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FOR SPACE STANDARDIZATION

Space product assurance

Material selection for controlling stress-corrosion cracking

ECSS Secretariat
ESA-ESTEC
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Noordwijk, The Netherlands

Foreword

This Standard is one of the series of ECSS Standards intended to be applied together for the management, engineering and product assurance in space projects and applications. ECSS is a cooperative effort of the European Space Agency, national space agencies and European industry associations for the purpose of developing and maintaining common standards. Requirements in this Standard are defined in terms of what shall be accomplished, rather than in terms of how to organize and perform the necessary work. This allows existing organizational structures and methods to be applied where they are effective, and for the structures and methods to evolve as necessary without rewriting the standards.

This Standard has been prepared by the ECSS Executive Secretariat, endorsed by the Document and Discipline Focal points, and approved by the ECSS Technical Authority.

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ECSS-Q-ST-70-36C 6 March 2009	Second issue The main changes between ECSS-Q-70-36A and the current version are the following: • Redrafting of ECSS-Q-70-36A according to new ECSS drafting rules and template • Correcting editorial mistakes raised by TA votes • Modifying the wording of requirements 5.3a and 5.3d to make them unambiguous • Inserting “Cast alloy Magnesium ELEKTRON 21 T6” in Table 5-1(e)

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1 Scope

This Standard covers the following processes of the general materials, mechanicals parts and processes (MMPP) flow of ECSS-Q-ST-70:

- The selection of metal alloys for which preference is given to approved data sources (Table 5-1 to Table 5-3)
- The criticality analysis to determine if a stress corrosion cracking (SCC) evaluation is necessary

This Standard sets forth the criteria to be used in the selection of materials for spacecraft and associated equipment and facilities so that failure resulting from stress-corrosion is prevented.

It is intended to provide general criteria to be used in stress-corrosion cracking control, which begins during design thanks to a methodological material selection.

This document does not intend to include all factors and criteria necessary for the total control of stress-corrosion cracking in all alloys.

The criteria established in this Standard are only applicable to designs for service involving exposure conditions similar to testing conditions

As regards weldments, this Standard is applicable to aluminium alloys, selected stainless steels in the 300 series and alloys listed in Table 5-1.

This Standard is not applicable to listed materials whose behaviour differs at elevated temperature and in specific chemical.

This standard may be tailored for the specific characteristic and constrains of a space project in conformance with ECSS-S-ST-00.

2
Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this ECSS Standard. For dated references, subsequent amendments to, or revision of any of these publications do not apply, However, parties to agreements based on this ECSS Standard are encouraged to investigate the possibility of applying the more recent editions of the normative documents indicated below. For undated references, the latest edition of the publication referred to applies.

ECSS-S-ST-00-01	ECSS system - Glossary of terms
ECSS-Q-ST-70	Space product assurance - Materials, mechanical parts and processes.
ECSS-Q-ST-70-37	Space product assurance - Determination of the susceptibility of metals to stress-corrosion cracking.
NASA-MSFC-SPEC 522B (July 1987)	Design criteria for controlling stress-corrosion cracking

3 Terms, definitions and abbreviated terms

3.1 Terms from other standards

For the purpose of this Standard, the terms and definitions from ECSS-ST-00-01 and ECSS-Q-ST-70 apply.

3.2 Terms specific to the present standard

3.2.1 stress-corrosion

combined action of sustained tensile stress and corrosion that can lead to the premature failure of materials

3.3 Abbreviated terms

For the purpose of this Standard, the abbreviated terms from ECSS-S-ST-00-01 and the following apply:

Abbreviation	Meaning
SCC	stress-corrosion cracking
SCEF	stress-corrosion evaluation form

4 Principles

4.1 Stress corrosion

Certain materials are more susceptible to stress corrosion cracking (SCC) than others. If a susceptible material is placed in service in a corrosive environment under tension of sufficient magnitude, and the duration of service is sufficient to permit the initiation and growth of cracks, failure occurs at a stress lower than that which the material is normally be expected to withstand. The corrosive environment need not be severe in terms of general corrosive attack.

NOTE Service failures due to stress-corrosion are frequently encountered in cases where the surfaces of the failed parts are not visibly corroded in a general sense.

Moreover, stresses are additive and threshold stresses for susceptibility are often low. There have been a number of stress-corrosion failures for which design stresses were intermittent and of short duration, and only of minor significance in contributing to failure. Stress-corrosion cracking in those cases occurred because of a combination of residual and assembly stresses not anticipated in design.

4.2 Evaluation of metal alloys

Resistance to stress- corrosion cracking of metal alloys depends mainly on factors:

- Grain orientation (see Annex D)
- Susceptibility to SCC (see Annex E)

5 Requirements

5.1 Stress corrosion cracking resistance evaluation of metal alloys

5.1.1 Overview

Clause 5.1.2 lists the requirements applicable for applications involving and identified as case 1:

- unlisted materials (i.e. materials not listed in tables 1, 2 or 3), or
- combinations of materials and environments outside the scope of this Standard

Clause 5.1.3 lists the requirements applicable for application involving listed materials with

- moderate SCC resistance,
- low SCC resistance, or
- moderate or low SCC resistance and coated or plated with materials with a high SCC resistance.

and identified as case 2.

NOTE The classes for high, moderated and low resistance to SCC are defined in ECSS-Q-ST-70-37.

5.1.2 Requirements for case 1

a. A request for evaluation shall be established in conformance with the DRD in Annex A.

b. As a reply to the customer request for SCC evaluation, the supplier shall provide a work proposal (including test specifications and procedures) in conformance with the DRD in Annex B.

NOTE An example of approved test specifications and procedures is ECSS-Q-ST-70-37.

c. The supplier shall perform a detailed evaluation of susceptibility according to test specifications and procedures approved by the customer

NOTE This is often the case for many applications involving unfamiliar materials, or unusual combinations of materials and environments.

d. The results of stress corrosion cracking resistance evaluation shall be reported in conformance with DRD in Annex A of ECSS-Q-ST-70-37.

e. The SCC test report shall be submitted for customer's approval before the material under evaluation is used or incorporated in a design.

5.1.3 Requirements for Case 2

a. The supplier shall provide the SCEF in conformance with the DRD in Annex C.

5.2 Materials selection criteria

5.2.1 General

a. The supplier shall use in preference high SCC resistance alloys listed in Table 5-1.

NOTE Selecting an alloy from this table avoid the need to perform a stress corrosion evaluation

5.2.2 High SCC resistance alloys

5.2.2.1 Surface treated materials

a. Alloys which are surface treated shall be evaluated according to 5.1.3a.

NOTE 1 For example:

- Metals having been treated with surface treatments such as nitriding and carburising.
- A low-strength plain carbon steel, carburised on the surface to a hardness corresponding to a tensile strength above 1 370 MPa (200 ksi).

NOTE 2 Surface treatment such as nitriding and carburising can make a stress-corrosion evaluation necessary for a material not normally considered susceptible.

5.2.3 Moderate SCC resistance alloys

5.2.3.1 Coated and plated materials

a. Alloys with moderate SCC resistance and coated or plated with materials with a high SCC resistance shall be evaluated according to 5.1.3a.

NOTE 1 For example: Even though 2024-T6 aluminium is anodised, this material has moderate resistance to stress corrosion.

NOTE 2 All electroplated, anodised and chemical-conversion coatings on otherwise acceptable materials are excluded from the requirements of this specification

5.2.3.2 Thin materials (alloy or temper of metal)

a. Sheet material less than 6,5 mm (0,250 inch) thick of the aluminium alloys listed in Table 5-2 do not require a SCEF according to Annex C.

b. Alloys used for electrical wiring, thermocouple wires, magnet windings and similar non-structural electrical applications do not require a SCEF according to Annex C.

5.2.3.3 Others

a. Alloys and tempers listed in Table 5-2 shall only be considered for use when a suitable alloy cannot be found in Table 5-1.

b. Materials listed in Table 5-2 shall not be used for applications involving high installation stress.

NOTE Examples of application involving high stress are springs or fasteners

5.2.4 Low SCC resistance alloys

a. Alloys and tempers listed in Table 5-3 shall only be considered for use in applications where the probability of stress-corrosion is remote.

5.2.4.2 Coated and plated materials

a. Alloys with low SCC resistance and coated or plated with materials with a high SCC resistance shall be evaluated according to 5.1.3a.

NOTE 1 For example: Even 440C stainless steel is chrome plated, this material has low resistance to stress corrosion.

NOTE 2 All electroplated, anodised and chemical-conversion coatings on otherwise acceptable materials are excluded from the requirements of this specification

5.2.5 Unlisted materials

a. The stress-corrosion resistance of alloys and weldments not listed in this document shall be ascertained:

1. by means of tests conducted in an environment representative of the proposed application, or
2. by means of direct comparison with similar alloys and weldments for which susceptibility is known to be low.

5.3 Design and assembly

a. The directional variation of the alloy shall be considered in the design of the manufactured product.

NOTE 1 The directional variation can be appreciable with respect to SCC.

NOTE 2 This is necessary for the evaluation of the susceptibility to stress corrosion cracking.

b. The supplier shall include both the residual stress distribution and the grain orientation in designing a part to be machined from wrought aluminium.

c. During design and assembly, the supplier shall avoid tension which is applied in transverse directions.

NOTE For example: Figure D-2 and Figure D-3 in Annex D illustrate undesirable situations.

d. The supplier shall ensure that stress corrosion threshold stresses are not exceeded by the combination of the following sources of stresses:

1. residual and assembly stress;
2. stresses resulting from operational, transportation and storage loads;
3. assembly stresses result from improper tolerances during fit-up, overtorquing, press fits, high-interference fasteners and welding;

   NOTE See for examples Figure D-2 and Figure D-3.

4. residual stresses as a result of machining, forming and heat-treating operations.

5.4 Customer's approval

a. The customer shall approve the SCEF before any of the following alloy, temper or weldment can be used or incorporated in a design:

1. coated, plated or surface-treated alloys, and weldments listed in Table 5-1;
2. any alloys, tempers and weldments listed in Table 5-2;
3. any alloys, tempers and weldments listed in Table 5-3;

4. any alloys, tempers and weldments not listed in this Standard.

NOTE In special cases where specific data are already available on a material under environmental conditions representative of anticipated exposure, a stress-corrosion evaluation form for use of this material within prescribed limits can be submitted for approval.

Table 5-1: Alloys with high resistance to stress-corrosion cracking

(a) Steel	Condition
Carbon steel (1000 series)	Below 1 225 MPa (180 ksi) UTS
Low alloy steel (4130, 4340, etc.)	Below 1 225 MPa (180 ksi) UTS[1]
(E) D6AC, H-11	Below 1 450 MPa (210 ksi) UTS
Music wire (ASTM 228)	Cold drawn
HY-80 steel	Quenched and tempered
HY-130 steel	Quenched and tempered
HY-140 steel	Quenched and tempered
1095 spring steel	Quenched and tempered
300 series stainless steel (unsensitized)[2]	All
400 series Ferritec stainless steel (404, 430, 431, 444, etc.)	All
21-6-9 stainless steel	All
Carpenter 20 Cb stainless steel	All
Carpenter 20 Cb-3 stainless steel	All
A286 stainless steel	All
AM350 stainless steel	SCT 1000[4] and above
AM355 stainless steel	SCT 1000 and above
Almar 362 stainless steel	H1000[5] and above
Custom 450 stainless steel	H1000 and above
Custom 455 stainless steel	H1000 and above
15-5 PH stainless steel	H1000 and above
PH 14-8 Mo stainless steel	CH900 and SRH950 and above[6,7]
PH 15-7 Mo stainless steel	CH900
17-7 PH stainless steel	CH900
Nitronic 33[3]	All
(E) Maraging steel MARVAL X12	All

1. A small number of laboratory failures of specimens cut from plate more than 2 inches thick have been observed at 75 % yield, even within this ultimate strength range. The use of thick plate should therefore be avoided in a corrosive environment when sustained tensile stress in the short transverse direction is expected.
2. Including weldments of 304L, 316L, 321 and 347.
3. Including weldments.
4. SCT 1000 = sub-zero cooling and tempering at 538 °C (1 000 °F).
5. H1000 hardened above 538 °C (1 000°F).
6. CH900 cold worked and aged at 480 °C (900 °F).
7. SRH950 = solution treated and tempered at 510 °C (950 °F).

(E) ESA classification not in NASA MSFC-SPEC-522A.

Table 5-1: Alloys with high resistance to stress-corrosion cracking *(cont.)*

(b) Nickel Alloy	**Condition**
Hastelloy C	All
Hastelloy X	All
Incoloy 800	All
Incoloy 901	All
Incoloy 903	All
Inconel 600[3]	Annealed
Inconel 625	Annealed
Inconel 718[3]	All
Inconel X-750	All
Monel K-500	All
Ni-Span-C 902	All
René 41	All
Unitemp 212	All
Waspaloy	All
3. Including weldments	

Table 5-1: Alloys with high resistance to stress-corrosion cracking *(cont.)*

(c) Aluminium alloys:			
Wrought[1,2]		**Cast**	
Alloy	**Condition**	**Alloy[3]**	**Condition**
1000 series	All	355.0, C355.0	T6
2011	T8	356.0, A356.0	All
2024, rod bar	T8	357.0	All
2219	T6, T8	B358.0 (Tens-50)	All
(E) 2419	T8	359.0	All
(E) 2618	T6, T8	380.0, A380.0	As cast
3000 series	All	514.0 (214)	As cast[5]
5000 series	All[4,5]	518.0 (218)	As cast[5]
6000 series	All	535.0 (Almag 35)	As cast[5]
(E) 7020	T6[6]	A712.0, C712.0	As cast
7049	T73		
7149	T73		
7050	T73		
7075	T73		
7475	T73		

1. Mechanical stress relieved (TX5X or TX5XX) where possible.
2. Including weldments of the weldable alloys.
3. The former designation is shown in parenthesis when significantly different.
4. High magnesium content alloys 5456, 5083 and 5086 should be used only in controlled tempers (H111, H112, H116, H117, H323, H343) for resistance to stress-corrosion cracking and exfoliation.
5. Alloys with magnesium content greater than 3,0 % are not recommended for high-temperature application, 66 °C (150 °F) and above.
6. Excluding weldments.

(E) ESA classification - not in NASA MSFC-SPEC-522A.

Table 5-1: Alloys with high resistance to stress-corrosion cracking *(cont.)*

(d) Copper Alloy	
CDA no. [1]	**Condition (% cold rolled)** [2]
110	37
170	AT, HT [3,4]
172	AT, HT [3,4]
194	37
195	90
230	40
422	37
443	10
510	37
521	37
619	40 (9 % B phase)
619	40 (95 % B phase)
688	40
706	50
725	50, annealed
280, 524, 606, 632, 655, 704, 710	0
715, (E) 917, (E) 937	0

1. Copper Development Association alloy number.
2. Maximum per cent cold rolled for which stress-corrosion-cracking data are available.
3. AT - annealed and precipitation hardened.
4. HT - work hardened and precipitation hardened.

(E) ESA classification not in NASA MSFC-SPEC-522A.

Table 5-1: Alloys with high resistance to stress-corrosion cracking *(cont.)*

(e) Miscellaneous Alloy (wrought)	Condition
Beryllium, S-200C	Annealed
HS 25 (L605)	All
HS 188	All
MP35N	All
Titanium, 3Al-2.5V	All
Titanium, 6AI-4V	All
Titanium, 13V-11Cr-3AI	All
(E) Titanium OMI 685, IMI 829	All
Magnesium, M1A	All
Magnesium, LA141	Stabilised
Magnesium, LAZ933	All
(E) Cast alloy Magnesium ELEKTRON 21	T6
(E) ESA classification not in NASA MSFC-SPEC-522A.	

Table 5-2: Alloys with moderate resistance to stress-corrosion cracking

(a) Steel Alloy	Condition
Carbon steel (1000 series)	1 225 to 1 370 MPa
Low-alloy steel (4130, 4340, etc.)	1 225 to 1 370 MPa
Nitronic 32	All
Nitronic 60	All
403, 410, 416, 431 stainless steel	(see footnote 1)
PH 13-8 Mo stainless steel	All
15-5PH stainless steel	Below H1000 [2]
17-4PH stainless steel	All
1. Tempering between 370 °C and 600 °C should be avoided because corrosion and stress-corrosion resistance is lowered. 2. H1000 = hardened above 538 °C (1 000 °F).	

Table 5-2: Alloys with moderate resistance to stress-corrosion cracking (cont.)

(b) Miscellaneous Alloy	Condition
Magnesium, AZ31B	All
Magnesium, ZK60A	All
Magnesium (E) ZW3	
(E) ESA classification not in NASA MSFC-SPEC-522A.	

Table 5-2: Alloys with moderate resistance to stress-corrosion cracking (cont.)

(c) Aluminium alloys[1,2]			
Wrought		**Cast**	
Alloy	**Condition**	**Alloy**	**Condition**
2024 rod, bar, extrusion	T6, T62	319.0, A319.0	As cast
2024 plate, extrusions	T8	333.0, A333.0	As cast
2124 plate	T8		
2048 plate	T8		
4032	T6		
5083	All [3]		
5086	All [3]		
5456	All [3]		
7001	T75, T76		
(E) 7010	T736		
7049	T76		
7050	T736,T76		
7075	T76		
7175	T736,T76		
7475	T76		
7178	T76		
(E) Russian Al-Li 1420 and 1421	soln. treat + age		

1. Mechanically stress relieved products (TX5X or TX5XX) should be specified where possible.
2. Sheet, unmachined extrusions and unmachined plate are the most resistant forms.
3. Except for controlled tempers listed in footnote 3 of Table I (c), aluminium alloys. These alloys are not recommended for high-temperature application, 66 °C (150 °F) and above.

(E) ESA classification - not in NASA MSFC-SPEC-522A.

Table 5-3: Alloys with low resistance to stress-corrosion cracking

(a) Steel Alloy	Condition
Carbon steel (1000 series)	Above 1 370 MPa
Low-alloy steel (4130, 4340, etc.)	Above 1 370 MPa
(E) D6AC, H-11 steel	Above 1 450 MPa
440C stainless steel	All
18 Ni Maraging steel, 200 grade	Aged at 900 °F
18 Ni Maraging steel, 250 grade	Aged at 900 °F
18 Ni Maraging steel, 300 grade	Aged at 900 °F
18 Ni Maraging steel, 350 grade	Aged at 900 °F
AM 350 stainless steel	Below SCT 1000
AM 355 stainless steel	Below SCT 1000
Custom 455 stainless steel	Below H1000
PH 15-7 Mo stainless steel	All except CH900
17-7 PH stainless steel	All except CH900
(E) Kovar	All
(E) ESA classification not in NASA MSFC-SPEC-522A.	

Table 5-3: Alloys with low resistance to stress-corrosion cracking *(cont.)*

(b) Aluminium Alloys[1,2]			
Wrought		**Cast**	
Alloy	**Condition**	**Alloy**	**Condition**
2011	T3, T4	295.0 (195)	T6
2014	All	B295.0 (B195)	T6
2017	All	520.0 (220)	T4
2024	T3, T4	707.0 (607, tern-alloy 7)	T6
2024 Forgings	T6, T62, T8	D712.0 (D612,40E)	As cast
2024 Plate	T62		
(E) Al-Li 2080	T8		
(E) 2618	T3, T4		
7001	T6		
7005	All		
(E) 7020	Weldments		
7039	All		
7075	T6		
7175	T6		
7079	T6		
7178	T6		
7475	T6		
(E) Al-Li 8090	All		
(E) BS L93	T6		
(E) Russian Al-Li 1441 and 1460	All		
1. Mechanically stress-relieved products (TX5X or TX5XX) should be specified where possible 2. Sheet, unmachined extrusions and unmachined plate are the least susceptible (E) ESA classification - not in NASA MSFC-SPEC-522A.forms			

Table 5-3: Alloys with low resistance to stress-corrosion cracking *(cont.)*

(c) Copper alloys	
CDA no.[1]	**Condition (% cold rolled)[2]**
260	50
353	50
443	40
672	50, annealed
687	10, 40
762	A, 25, 50
766	38
770	38, 50, annealed
782	50
1. Copper Development Association alloy number. 2. Rating based on listed conditions only.	

Table 5-3: Alloys with low resistance to stress-corrosion cracking *(cont.)*

(d) Magnesium Alloy	**Condition**
AZ61A	All
AZ80A	All
WE54	All
ZCM711	All

Annex A (normative) Request for SCC resistance evaluation - DRD

A.1 DRD identification

A.1.1 Requirement identification and source document

This DRD is called from ECSS-Q-ST-70-36, requirement 5.1.2a.

A.1.2 Purpose and objective

The purpose of the request for SCC resistance evaluation is to confirm that the materials is to be evaluated with respect to the specific SCC resistance test specification of the project and prior to its validation and approval for selection as item of the DML.

A.2 Expected response

A.2.1 Scope and content

a. The Request for SCC resistance evaluation shall include or refer to the following information:

1. objective of the test activity,
2. background and justification to the test activity,
3. material to be investigated,
4. description of test activity, and
5. deliverables.

A.2.2 Special remarks

None.

Annex B (normative) SCC resistance test specifications and procedures (Work Proposal) - DRD

B.1 DRD identification

B.1.1 Requirement identification and source document

This DRD is called from ECSS-Q-ST-70-36, requirement 5.1.2b.

B.1.2 Purpose and objective

The work proposal is a document that defines the stress corrosion cracking resistance test specification and procedures proposed by the test house. The work proposal for SCC resistance testing of metals alloys is prepared by the test house, which is responsible for the test activity, and it is submitted to the customer for review and approval

B.2 Expected response

B.2.1 Scope and content

a. The WP shall include a proposed work description giving:

1. the objectives of the test activity,
2. test procedure and reference to standards,
3. materials, number and dimensions of samples,
4. test conditions,

   NOTE For example: environment, properties evaluated and measurement techniques.

5. expected test output.

b. The WP shall include a proposed settlement describing the test procedures and any deviation from the conditions initially requested by the customer in the Request for SCC resistance evaluation.

B.2.2 Special remarks

None.

Annex C (normative) Stress-corrosion evaluation form (SCEF) - DRD

C.1 DRD identification

C.1.1 Requirement identification and source document

This DRD is called from ECSS-Q-ST-70-36, requirement 5.1.3a

C.1.2 Purpose and objective

The objective of the stress-corrosion evaluation form (SCEF) is to conduct a detailed evaluation of susceptibility in order to ensure adequate stress-corrosion resistance in applications involving unfamiliar materials, or unusual combinations of materials and environments.

C.2 Expected response

C.2.1 Scope and content

<1> Originator

a. The SCEF shall contain the name, organization and address of the originator.

<2> System / Subsystem

a. The SCEF shall contain the name of the system/subsytem on which the material is used.

<3> Project

a. The SCEF shall contain the name of the project on which the material is used.

<4> Declared material list identification

a. The SCEF shall contain the declared material list identification.

<5> Use and location

a. The SCEF shall contain the use and location planned for the material.

<6> Number of identical parts

a. The SCEF shall contain the number of identical parts.

<7> Manufacturer

a. The SCEF shall contain the name of the manufacturer.

<8> Material

a. The material shall be identified as specified on figure xxx.

b. Specific alloy and temper designation of raw material from which the part is fabricated shall be given.

<9> Heat treatment

a. All thermal treatments which the part receives shall be listed.

<10> Size and form

a. Approximate dimensions of raw material from which the part is fabricated shall be listed.

b. The raw material form shall be mentioned.

NOTE For example: bar, plate, sheet, extrusion, and forging.

<11> Sustained tensile stresses

a. An estimate of stresses shall be carried out.

b. Stresses shall be listed according to their source following:

— 11.a.: Process

— 11.b.: Assembly

— 11.c.: Design

c. Stresses shall be listed according to the basis on which the estimate has been made.

d. The direction of the resultant stresses shall be indicated with respect to the grain orientation of the material.

e. Reference shall be made to all instances when machining or other metal-removal operations expose short transverse grain orientation to stress.

NOTE For example: Following machining of forged parts; removal of clad surfaces.

f. Any special precautions taken to control stresses shall be noted.

<12> Special processing

a. Any processes used for reducing tensile stresses shall be noted, if relevant.

NOTE For example: Shot peening or stress-relief treatments.

<13> Weldments

a. A stress-corrosion cracking evaluation of all weldments shall be made.

b. All information relevant for the stress-corrosion cracking evaluation shall be submitted:

1. alloy, form and temper of the parent metal;
2. filler alloy, if any;
3. welding process;
4. weld bead removed;
5. post-weld thermal treatment or stress relief.

<14> Environment

a. The corrosive environment to which the part is exposed during its lifetime shall be evaluated.

b. The evaluation shall include the following elements:

1. exposure during fabrication;
2. exposure during assembly;
3. exposure during component storage;
4. environmental conditions during use.

<15> Protective finish

a. Any corrosion-protective finish applied shall be listed.

b. Any finish that can affect the basic corrosion resistance of the component shall be listed.

<16> Function of part

a. The basic function of the part shall be listed.

b. If more pertinent, the basic function of the assembly shall be listed in replacement of the basic function of the part.

<17> Effect of failure

a. The possible effects of the failure of the part or assembly on the overall function or mission of the major assembly involved shall be listed.

<18> Evaluation of stress-corrosion susceptibility

a. The SCEF shall contain the rationale underlying the material selection and a short explanation as to why no stress-corrosion problem is expected.

<19> Remarks

a. The SCEF shall contain any additional information or explanatory notes not included in the preceding sections.

NOTE Relevant laboratory reports can be referenced.

C.2.2 Special remarks

C.2.2.1. Stress-corrosion evaluation form

Originator (Name, Organization, Address):
Used on system/subsystem:
Project:
1. Declared material list identification
2. Use and location
3. Number of identical parts
4. Manufacturer
5. Material
6. Heat treatment
7. Size and form
8. Sustained tensile stresses - magnitude and direction:
a. Process residual
b. Assembly
c. Design, static
9. Special processing
10. Weldments:
a. Alloy form, temper of parent metal
b. Filler alloy (if none, indicate)
c. Welding process
d. Weld bead removed: Yes ( ) No ( )
e. Post–weld thermal treatment
f. Post–weld stress relief
11. Environment
12. Protective finish
13. Function of part
14. Effect of failure
15. Evaluation of stress–corrosion susceptibility
16. Remarks

Figure C-1: Example of a Stress-corrosion evaluation form

C.2.2.2. Annexes

a. Annexes may be supplied with the stress-corrosion evaluation form.

NOTE For example: Construction drawings for intended use or laboratory stress-corrosion test report, as per clause xx.xx of *Standard_Reference*.

Annex D (informative) Grain orientation

D.1 Introduction

Rolling, extrusion and forging are the most common processing operations employed in the production of standard forms of wrought metal. All of these produce a flow of metal in a predominant direction so that when viewed microscopically, is the metal neither isotropic nor homogeneous. As a result, the properties of the metal vary according to the direction in which they are measured. The extent of directional variation depends on the property of interest.

D.2 Anisotropy of grain orientation

The anisotropy of grain orientation, produced by rolling and extruding, is illustrated in Figure D-1. Taking the rolled plate as an example, it is conventional to describe the direction of rolling as the longitudinal direction, the direction perpendicular to the longitudinal axis and in the plane of the plate as the long transverse direction, and the direction through the thickness of the plate as the short transverse direction.

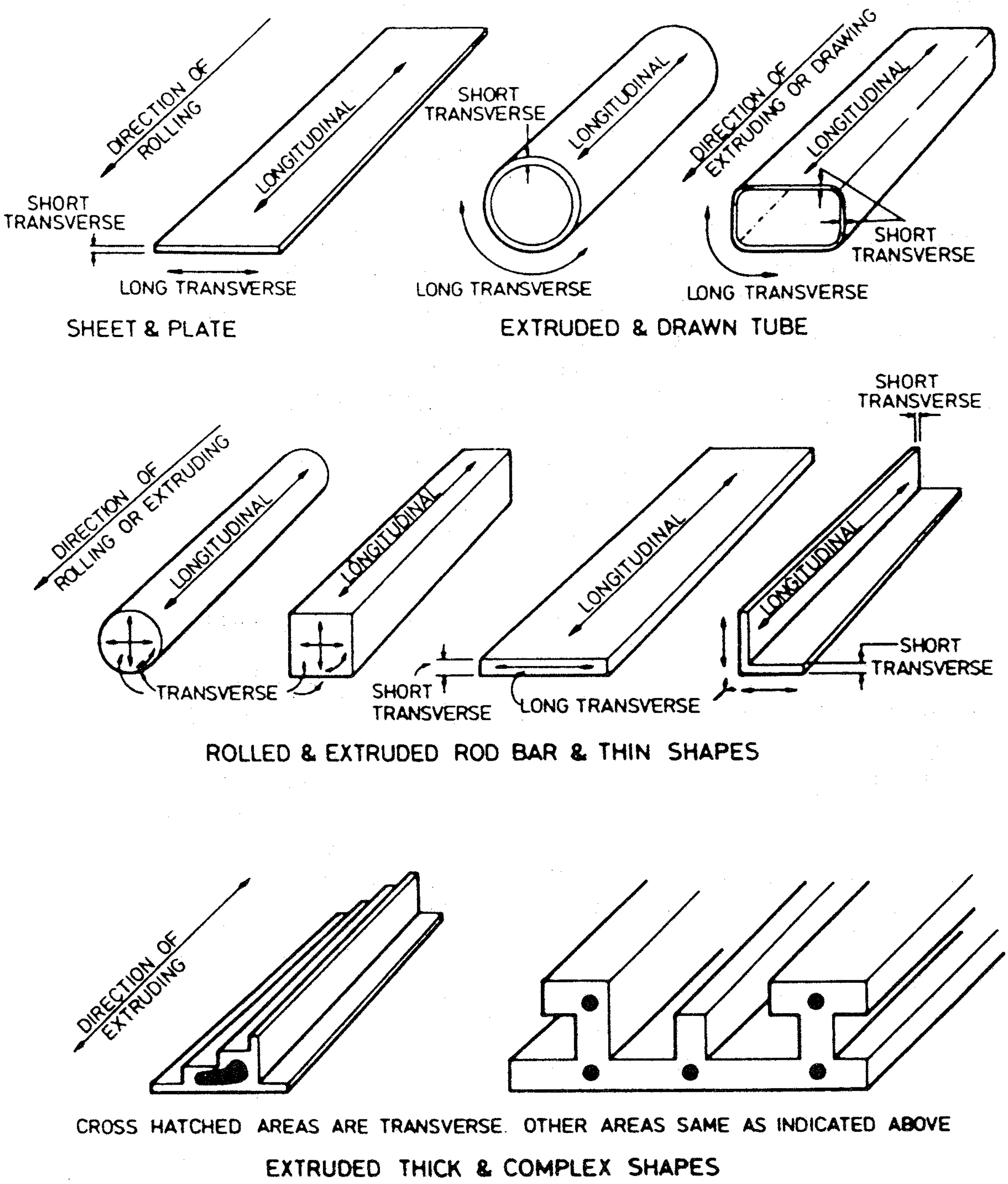


Figure D-1: Grain orientations in standard wrought forms

For certain shapes, it is not possible to distinguish both a long and a short transverse direction on the basis of the simple rules for identifying those directions in a plate.

NOTE As an example, consider the thick tee illustrated in Figure D-2, where a region with both long and short transverse orientations has been identified on the basis of experience with that particular shape and a knowledge of the forming method.

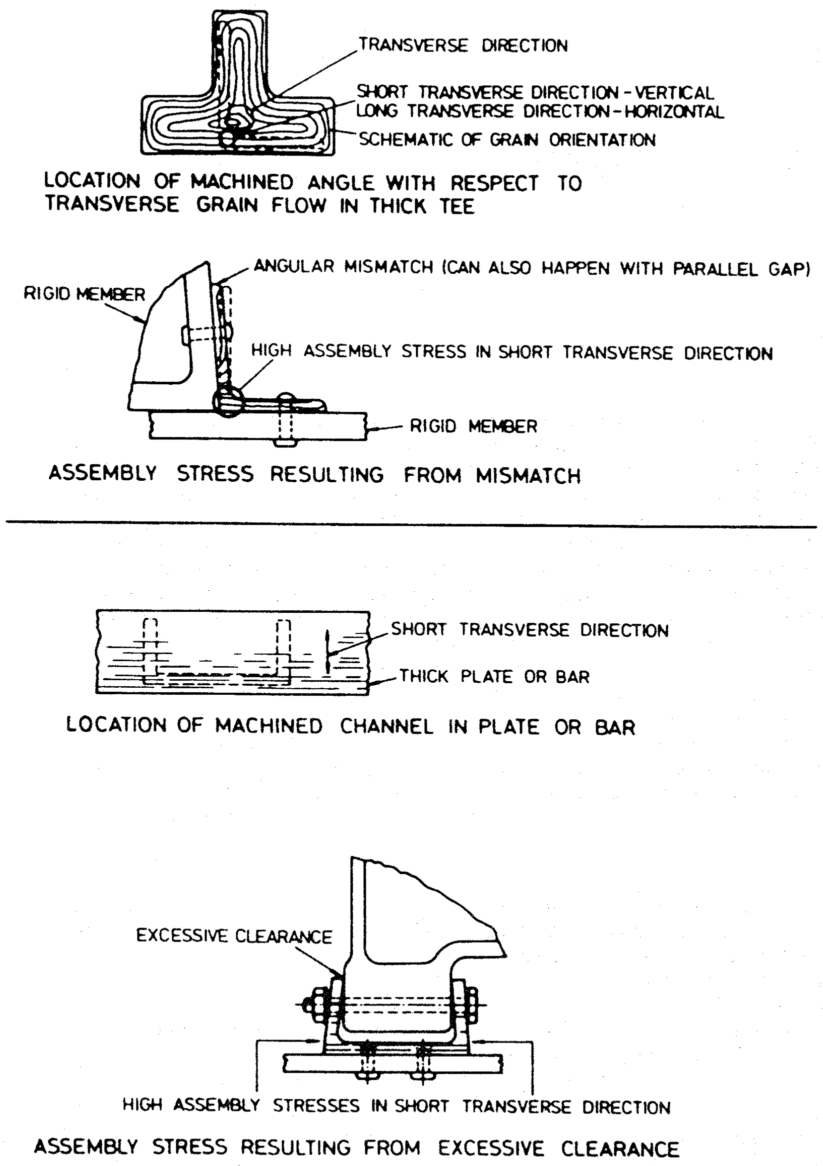


Figure D-2: Examples of tensile stresses in short transverse direction applied during assembly

Forgings also require special consideration when identifying the short transverse direction. In a forging operation, the flow of metal is influenced and constrained by the shape of the die cavity. For complex shapes, there may be several regions where a short transverse direction exists. The direction perpendicular to the parting plane of the dies is always short transverse, as illustrated in Figure D-3

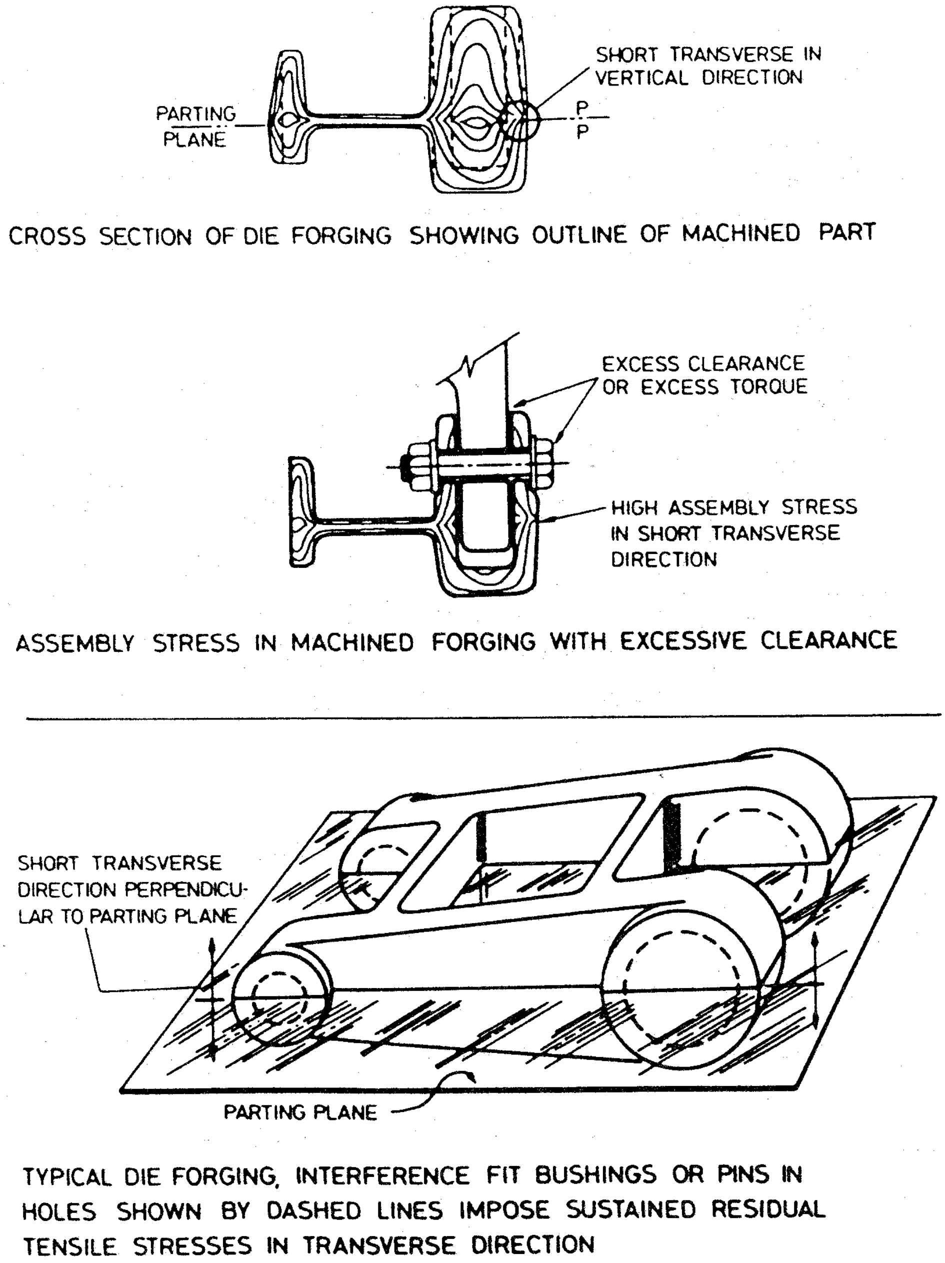


Figure D-3: Examples of tensile stresses in short transverse direction resulting from assembly

The resistance of metals, particularly alloys of aluminium, to stress-corrosion cracking is always less when tension is applied in a transverse direction. It is least for the short transverse direction. Figure D-2 and Figure D-3 were drawn to illustrate undesirable situations in which tensile stresses due to assembly have been applied in the short transverse direction.

Annex E (informative) SCC resistance of alloys

E.1 Stress corrosion susceptibility

The stress-corrosion susceptibility of alloys included in this document was determined at ambient temperature:

- by means of laboratory tests in which specimens were either sprayed with salt water or periodically immersed (every xx days/mn/sec) and withdrawn;
- by exposing specimens in sea coast or mild industrial environments;
- Example of mild industrial environment;
- by subjecting fabricated hardware to service conditions.

NOTE 1 For example: Example of service condition for a given hardware

NOTE 2 Use of the criteria established herein should therefore be limited to designs for service involving similar exposure conditions.

Weldments present specific problems, as described in *Document_Reference*, in designing for resistance to SCC. In addition to the susceptibility of the parent metals, it is also necessary to consider the filler metal and the microstructural effects of heat introduced by the welding operations and subsequent heat treatments, such as *Subsequent_Heat_Treatment_Example*. Because of the additional variables to be considered (*Additional_Variables_List*), susceptibility data are not as extensive for weldments as for alloys in mill form.

In designing for stress-corrosion resistance, it is important to realize that stresses are additive and that threshold stresses for susceptibility are often low. There have been a number of stress-corrosion failures for which design stresses were intermittent and of short duration, and only of minor significance in contributing to failure. Stress-corrosion cracking in those cases occurred because a combination of residual and assembly stresses not even anticipated in design. Unfortunately, for most service environments, accurate threshold stresses are difficult to assess. In addition to stresses resulting from operational, transportation and storage loads that are anticipated during design, assembly and residual stresses also contribute to stress-corrosion failure.

E.2 Metal alloys

E.2.1 Aluminium

Many aluminium alloys exhibit excellent resistance to stress-corrosion cracking in all standard tempers. The high-strength alloys, however, which are of primary interest in aerospace applications, is approached cautiously. Some are resistant only in the longitudinal grain direction, and the resistance of others varies with the specific temper. Because metallurgical processing of aluminium alloys usually results in a pronounced elongation of grains, the variation of susceptibility with grain orientation is more extensive than for other metals. Also, because conventional processing methods are designed to optimise strength, residual stresses - especially in thick sections - are usually greater in aluminium products than in wrought forms of other metals. For this reason, wrought, heat-treatable aluminium products specified for use in the fabrication of hardware should be mechanically stress relieved (the TX5X or TX5XX temper designations) whenever possible.

Both the residual stress distribution and the grain orientation are carefully considered, as specified in clause 5.3, in designing a part to be machined from wrought aluminium. Machining does not only alter the stress distribution but, as indicated in Figure D-2, it can also result in the exposure of a short transverse region on the surface of the finished part which is subjected to tension in service.

E.2.2 Steel

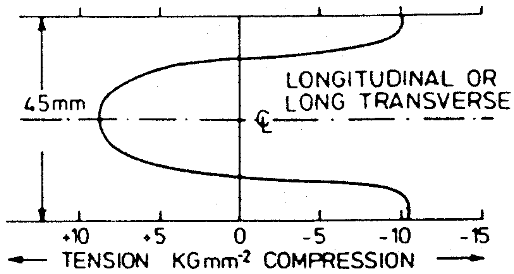
Carbon and low-alloy steels with ultimate tensile strengths below 1 225 MPa (180 ksi) are generally resistant to stress-corrosion cracking. Austenitic stainless steels of the 300 series are generally resistant. Martensitic stainless steels of the 400 series are more or less susceptible, depending on composition and heat treatment. Precipitation-hardening stainless steels vary in susceptibility from extremely high to extremely low, depending on composition and heat treatment. The susceptibility of these steels is particularly sensitive to heat treatment, and special vigilance is required to avoid problems due to stress-corrosion cracking.

E.2.3 Nickel

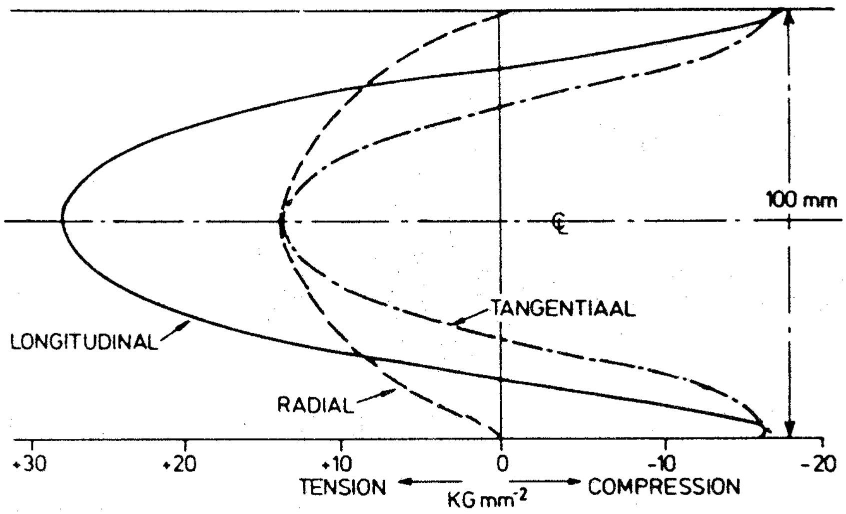
As a class, alloys with high nickel content are resistant to stress-corrosion cracking.

E.2.4 Copper

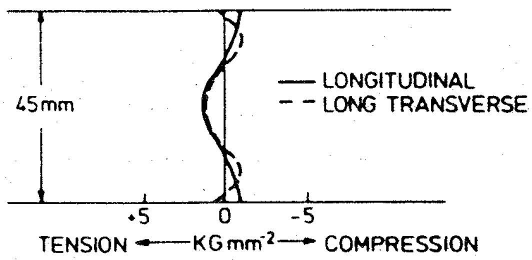
Natural atmospheres containing the pollutants sulphur dioxide, oxides of nitrogen, and ammonia are reported to cause stress-corrosion cracking of some copper alloys. Chlorides present in marine atmospheres may cause stress-corrosion problems, but to a lesser extent than the previously listed pollutants, which indicates that industrial areas are probably more aggressive than marine sites to copper-base alloys. Many copper alloys containing over 20 % zinc are susceptible to stress-corrosion cracking even in the presence of alloying additions that normally impart resistance to stress-corrosion.



7075-T6 PLATE. QUENCHED IN COLD WATER AND NOT STRESS RELIEVED



7075-T6 ROD. QUENCHED IN COLD WATER AND NOT STRESS RELIEVED



7075-T651 PLATE, STRETCHED 2% AFTER COLD WATER QUENCH

Figure E-1: Typical residual stress distributions in 7075 Aluminium alloys

Annex F (informative) Stress sources

F.1 Introduction

In addition to stresses resulting from operational, transportation and storage loads that are anticipated during design, assembly and residual stresses also contribute to stress-corrosion, and in many cases are the major contributors to stress-corrosion failure.

F.2 Stress sources

Table F-1: Sources of stress

Stress type	Source
Assembly	• improper tolerances during fit-up (Figure D-3 and Figure E-1) • overtorquing • press fits • high-interference fasteners • welding
Residual[1]	• machining • forming • heat-treating
Transportation	
Storage	
Operational	

1 Some typical residual-stress distributions through plate and rod are illustrated in Figure D-1 to provide an indication of the magnitudes of stress which can be developed as the result of conventional heat treating and forming operations.

Bibliography

ECSS-S-ST-00	ECSS system – Description, implementation and general requirements