SLOVENSKI STANDARD
SIST EN 14607-8:2005

01-januar-2005

Vesoljska tehnika – Mehanika - 8. del: Materiali

Space engineering - Mechanical - Part 8: Materials

Raumfahrttechnik - Mechanik - Teil 8: Werkstoffe

Ingénierie spatiale - Mécanique - Partie 8: Matériaux

Ta slovenski standard je istoveten z: **EN 14607-8:2004**

ICS:

49.140	Vesoljski sistemi in operacije	Space systems and operations

SIST EN 14607-8:2005 **en**

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 14607-8

August 2004

ICS 49.140

English version

Space engineering - Mechanical - Part 8: Materials

Ingénierie spatiale - Mécanique - Partie 8: Matériaux

Raumfahrttechnik - Mechanik - Teil 8: Werkstoffe

This European Standard was approved by CEN on 27 June 2003.

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This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

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Ref. No. EN 14607-8:2004: E

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Foreword

This document (EN 14607-8:2004) has been prepared by CMC.

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of an identical text or by endorsement, at the latest by February 2005, and conflicting national standards shall be withdrawn at the latest by February 2005.

It is based on a previous version[1)] originally prepared by the ECSS Mechanical Engineering Standard Working Group, reviewed by the ECSS Technical Panel and approved by the ECSS Steering Board. The European Cooperation for Space Standardization (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.

This document is one of the series of space standards intended to be applied together for the management, engineering and product assurance in space projects and applications.

Requirements in this document 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.

EN 14607 Space engineering - Mechanical is published in 8 Parts:

- Part 1: Thermal control
- Part 2: Structural
- Part 3: Mechanisms
- Part 4: ECLS
- Part 5: Propulsion
  - Part 5.1: Liquid and electric propulsion for spacecraft
  - Part 5.2: Solid propulsion for spacecraft, solid and liquid propulsion for launchers
- Part 6: Pyrotechnics
- Part 7: Mechanical parts
- Part 8: Materials

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

[1)] ECSS-E-30 Part 8A.

1 Scope

EN 14607 Part 8 of Space engineering - Mechanical defines the mechanical engineering requirements for materials.

This document also encompasses the effects of the natural and induced environments to which materials used for space applications can be subjected.

This document defines requirements for the establishment of the required mechanical and physical properties of the materials including the effects of the environmental conditions, material selection, procurement, production and verification. Verification includes destructive and non-destructive test methods. Material procurement and control is closely related to required quality assurance procedures and detailed references to EN 13291-3 are made.

When viewed from the perspective of a specific project context, the requirements defined in this document should be tailored to match the genuine requirements of a particular profile and circumstances of a project.

NOTE Tailoring is a process by which individual requirements of specifications, standards and related documents are evaluated, and made applicable to a specific project by selection, and in some exceptional cases, modification of existing or addition of new requirements.

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.

EN 13291-3, *Space product assurance — General requirements — Part 3: Materials, mechanical parts and processes*

EN 13701:2001, *Space systems — Glossary of terms*

EN 14607-2, *Space engineering — Mechanical — Part 2: Structural*

References to sources of approved lists, procedures and processes can be found in the bibliography.

3 Terms and definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 13701:2001 and the following apply.

3.1.1
A-basis design allowable
value which at least 99 % of the population of values is expected to fall with a confidence of 95 %

3.1.2
B-basis design allowable
value which at least 90 % of the population of values is expected to fall with a confidence of 95 %

3.1.3
composite sandwich construction
panels composed of a lightweight core material, such as honeycomb, foamed plastic, and so forth, to which two relatively thin, dense, high-strength or high stiffness faces or skins are adhered

3.1.4
corrosion
reaction of the engineering material with its environment with a consequent deterioration in properties of the material

3.1.5
Elastic modulus
the ratio between uniaxial stress and the strain

3.1.6
material design allowable
material property that has been determined from test data on a probability basis and has been chosen to assure a high degree of confidence in the integrity of the completed structure

3.1.7
micro-yield
applied force to produce a residual strain of 1×10^{-6} mm/m along the tensile or compression loading direction

3.1.8
polymer
high molecular weight organic compound, natural or synthetic, with a structure that can be represented by a repeated small unit, the mer

EXAMPLE Polyethylene, rubber, and cellulose.

3.2 Abbreviated terms

The following abbreviated terms are defined and used within this document.

Abbreviation	Meaning
ASTM	American Society for Testing Materials
CFRP	carbon fibre reinforced plastic
CMC	ceramic matrix composites
CME	coefficient of moisture expansion
CTE	coefficient of thermal expansion
DRD	document requirements definition
EB	electron beam
K_{ic}	plane strain critical stress intensity factor
K_{iscc}	plane strain critical stress intensity factor for a specific environment
LEO	low Earth orbit
MIG	metal inert gas
MMC	metal matrix composite
MoS_2	molybdenum disulphide
NDE	non-destructive evaluation
NDI	non-destructive inspection

NDT	non-destructive test
PTFE	polytetrafluoroethylene
RTM	resin transfer moulding
SCC	stress corrosion cracking
STS	space transportation system
TIG	tungsten inert gas
UD	uni-directional
UV	ultra violet

4 Requirements

4.1 General

4.1.1 Overview

This group of requirements covers the interaction of materials engineering requirements with project management, product assurance, and related requirements.

4.1.2 Applicability

This document applies to all materials used in all space and space related products. For certain projects, it can be necessary to include further (normative) standards in addition to those referenced within this document.

4.1.3 Controlling documentation

a) All materials and processes shall be defined by standards and specifications.

b) Suppliers shall select EN and ECSS Standards, supplemented by agency or company standards.

4.2 Mission

Mission requirements are covered in this document.

4.3 Functionality

4.3.1 Strength

a) Spacecraft design shall ensure the survival of the structure under the worst feasible combination of mechanical and thermal loads for the complete lifetime of the spacecraft.

b) A strength analysis shall be performed and demonstrate a positive margin of safety and include, if applicable, yield load analysis, ultimate load analysis and buckling load analysis (see EN 14607-2).

NOTE The strength of a material is highly dependant on the direction as well as on the sign of the applied load, e.g. axial tensile, and transverse compressive.

4.3.2 Elastic modulus

For composites the required elastic modulus shall be verified.

NOTE The elastic modulus for metals and alloys is weakly dependant on heat-treatment and orientation. However, for fibre reinforced materials, the elastic modulus depends on the fibre orientation.

4.3.3 Fatigue

For all components subject to alternating stresses, it shall be demonstrated that the degradation of material properties over the complete mission conforms to the specification.

NOTE Fatigue fracture can form in components which are subjected to alternating stresses. These stresses can exist far below the allowed static strength of the material.

4.3.4 Fracture toughness

a) For homogeneous materials the K_{ic} or K_{iscc} shall be measured according to approved procedures.

b) Metallic materials intended for use in corrosive surface environments shall be tested for fracture toughness under representative conditions.

NOTE The fracture toughness is a measure of the damage tolerance of a material containing initial flaws or cracks. The fracture toughness in metallic materials is described by the plain strain value of the critical stress intensity factor. The fracture toughness depends on the environment.

4.3.5 Creep

When creep is expected to occur, testing under representative service conditions shall be performed.

NOTE Creep is a time-dependant deformation of a material under an applied load. It usually occurs at elevated temperature, although some materials creep at room temperature. If permitted to continue indefinitely, creep terminates in rupture.
Extrapolations from simple to complex stress-temperature-time conditions are difficult.

4.3.6 Micro-yielding

a) Where dimensional stability requirements shall be met, micro-yielding shall be assessed.

b) When micro-yielding is expected to occur, testing and analysis in relation with the mechanical loading during the life cycle of the hardware shall be performed.

NOTE 1 Some materials can exhibit residual strain after mechanical loading.

NOTE 2 In general the most severe mechanical loading occurs during launch.

4.3.7 Coefficient of thermal expansion and coefficient of moisture expansion

a) Thermal coefficient mismatch between structural members shall be minimized such that stresses generated in the specified temperature range for the item are acceptable.

b) The coefficient of thermal expansion (CTE) of composite materials intended for high stability structural applications shall be systematically determined by means of dry test coupons under dry test conditions.

c) For hygroscopic materials intended for high stability structural applications, the coefficient of moisture expansion (CME) shall be systematically determined.

d) A sensitivity analysis which takes in consideration the inaccuracies inherent in the manufacturing process shall be performed for all composite materials.

NOTE The difference in thermal or moisture expansion between members of a construction or between the constituents of a composite or a coated material can induce large stresses or strains and can finally lead to failures.

4.3.8 Stress corrosion

a) Metallic structural products shall be selected from preferred lists.

b) The metallic components proposed for use in most spacecraft shall be screened to prevent failures resulting from stress corrosion cracking (SCC).

NOTE Stress corrosion cracking (SCC), defined as the combined action of a sustained tensile stress and corrosion, can cause the premature failure of metals.

c) Only those products found to possess a high resistance to stress corrosion cracking shall have unrestricted use in structural applications.

d) Materials selected for structural applications shall possess a high resistance to stress corrosion cracking, if they are

- exposed to a long-term storage on ground (terrestrial),
- flown on the Space Transportation System (STS),
- classified as fracture critical items, or
- parts associated with the fabrication of launch vehicles.

e) The technical criteria, for the selection of materials, of EN 13291-3 shall apply.

4.3.9 Corrosion fatigue

For all materials in contact with chemicals and experiencing an alternating loading it shall be demonstrated that the degradation of properties over the complete mission is acceptable.

NOTE Corrosion fatigue indicates crack formation and propagation caused by the effect of alternating loading in the presence of a corrosion process. Because of the time dependence of corrosion, the number of cycles before failure depends on the frequency of the loading. Since chemical attack takes time to take effect, its influence is greater as the frequency is reduced. No metals or alloys demonstrate complete resistance to corrosion fatigue.

4.3.10 Hydrogen embrittlement

The possibility of hydrogen embrittlement occurring during component manufacture or use shall be assessed. An appropriate material evaluation shall be undertaken including the assessment of adequate protection and control.

NOTE Metals can be embrittled by absorbed hydrogen to such a degree that the application of the smallest tensile stress can cause the formation of cracking.

The following are possible sources of hydrogen:

- thermal dissociation of water in metallurgical processes (e.g. casting and welding),
- decomposition of gases,
- pickling,
- corrosion,
- galvanic processes (e.g. plating), and
- ion bombardment.

4.3.11 Mechanical contact surface effects

a) For all solid surfaces in moving contact with other solid surfaces it shall be demonstrated that the degradation of surface properties over the complete mission is acceptable from a performance point of view.

NOTE 1 The friction behaviour of polymers differs from that of metals. The surfaces left in contact under load can creep and high local temperatures can be generated by frictional heating at regions of real contact.

NOTE 2 When clean surfaces are placed in contact they do not touch over the whole of their apparent area. The load is supported by surface irregularities and the following interactions can occur:

- elastic deformation,
- adhesion,
- plastic deformation,
- material transfer and removal,
- heat transfer chemical reaction,
- transformation of kinetic energy into heat energy, and
- diffusion or localized melting.

b) Structural applications shall be designed to avoid wear.

NOTE Wear is the progressive loss of material from the operating surface of a body occurring as a result of relative motion at the surface. Wear is generally considered to be detrimental, but in mild form it can be beneficial, e.g. during the running-in period of engineering surfaces.
The major types of wear are abrasive wear, adhesive wear, erosive wear, rolling wear and fretting.

c) For all solid surfaces in static contact with other solid surfaces and intended to be separated it shall be demonstrated that the increase in separation force during this physical contact conforms to the required performance.

NOTE For very clean surfaces strong adhesion occurs at the regions of real contact, a part of which can result in cold-welding.

4.4 Mission constraints

4.4.1 General

Product assurance requirements on mission constraints shall be in accordance with EN 13291-3.

4.4.2 Temperature

a) Material properties shall be compatible with the thermal environment to which they are exposed.

b) The passage through transition temperatures (e.g. brittle-ductile transitions or glass transition temperatures including the effects of moisture or other phase transitions) shall be taken into account.

NOTE Cryogenic tanks and thermal protection systems for re-entry applications are examples of the extremes of the temperature range. Temperatures below room temperature generally cause an increase in strength properties, with a reduction in the ductility. Ductility and strength can however either increase or decrease at temperatures above room temperature. This change depends on many factors, such as temperature and time of exposure.

4.4.3 Thermal cycling

Materials subject to thermal cycling shall be selected to ensure they are capable of withstanding the induced thermal stresses and shall be tested according to approved procedures.