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Vesoljska tehnika – Mehanika – 2. del: Konstrukcija

Space engineering - Mechanical - Part 2: Structural

Raumfahrttechnik - Mechanik - Teil 2: Strukturen

Ingénierie spatiale - Mécanique - Partie 2: Structure

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Space engineering - Mechanical - Part 2: Structural

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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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Foreword

This document (EN 14607-2:2004) 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of an identical text or by endorsement, at the latest by February 2005, and conflicting national standards shall be withdrawn at the latest by February 2005.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 European Cooperation for Space Standardization (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 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,

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[1] ECSS-E-30 Part 2A

Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

1 Scope

Part 2 of Space engineering - Mechanical defines the mechanical engineering requirements for structural engineering.

This document specifies the requirements to consider in all engineering aspects of structures: requirement definition and specification, design, development, verification, production, in-service and eventual disposal.

The document applies to all general structural subsystem aspects of space including: launch vehicles, transfer vehicles, re-entry vehicles, spacecraft, landing probes and rovers, sounding rockets, payloads and instruments, and structural parts of all subsystems.

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 13701:2001, Space systems — Glossary of terms.

ECSS-E-10, Space engineering — System engineering

3 Terms, definitions, abbreviated terms and units

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-value
mechanical property value above which at least 99 % of the population of values is expected to fall, with a confidence level of 95 %

NOTE A-value is also called A-allowable.

3.1.2
allowable stress (load)
maximum stress (load) in a structural part for a given operating environment to prevent rupture, collapse, detrimental deformation or unacceptable crack growth

3.1.3
B-value
mechanical property value above which at least 90 % of the population of values is expected to fall, with a confidence level of 95 %

NOTE B-value is also called B-allowable.

3.1.4
composite material
material that is made of two or more constituent materials

3.1.5
composite structure
structure composed of fibre-reinforced material, such as carbon, aramid or glass continuous aligned fibres in a resin, metallic or ceramic matrix

NOTE Fibre-reinforced plastic face sheeted sandwich panels containing light alloy or composite material cores are also defined as composite structures.

3.1.6
design load
limit load multiplied by a design factor

3.1.7
design parameters
physical features which influence the design performances

NOTE According to the nature of the design variables, different design problems can be identified such as:

- structural sizing for the dimensioning of beams, shells;
- shape optimization;
- material selection;
- structural topology.

3.1.8
dynamic load
time varying load with deterministic or stochastic distribution

3.1.9
factor of safety (FOS)
coefficient by which the design loads are multiplied in order to account for uncertainties in the statistical distribution of loads, uncertainties in structural analysis, manufacturing process, material properties and failure criteria

3.1.10
fail-safe
structure which is designed with sufficient redundancy to ensure that the failure of one structural element does not cause general failure of the entire structure with catastrophic consequences (e.g. loss of launcher and endangerment of human life)

NOTE Failure can be considered as rupture, collapse, seizure, excessive wear or any other phenomenon resulting in an inability to sustain limit loads, pressures or environments.

3.1.11
generalized mass
mass transformed by the mode shapes into the modal space (i.e. modal coordinates)

3.1.12
limit load
maximum load to be encountered in service with a given probability for a given design condition

3.1.13
margin of safety (MOS)
margin of the applied load multiplied by a factor of safety against the allowed load

3.1.14
maximum design pressure (MDP)
maximum pressure for which the system or component is designed

NOTE The MDP is always equal or larger than the MEOP.

3.1.15
maximum expected operating pressure (MEOP)
maximum pressure at which the system or component is expected to operate in a particular application

NOTE MEOP includes the effects of temperature, transient pressure peaks, vehicle acceleration and relief valve tolerance.

3.1.16
POGO
propulsion generated oscillations

3.1.17
primary structure
part of the structure that carries the main flight loads and defines the fundamental resonance frequencies

3.1.18
proof load
load applied during a proof test

3.1.19
random load
vibration load whose instantaneous magnitudes are specified only by probability distribution functions giving the probable fraction of the total time that the instantaneous magnitude lies within a specified range

NOTE Random load contains no periodic or quasi-periodic constituents.

3.1.20
safe life structure
structure which has no failure when subject to the cyclic and sustained loads and environments encountered in the service life

3.1.21
scatter factor
coefficient by which number of cycles or life time is multiplied in order to account for uncertainties in the statistical distribution of loads and cycles as well as uncertainties in fatigue analysis, manufacturing processes and material properties

3.1.22
secondary structure
structure attached to the primary structure with negligible participation in the main load transfer and the stiffness of which does not significantly influence the fundamental resonance frequencies

3.1.23
shock load
special type of transient load, where the load shows significant peaks and the duration of the load is well below the typical response time of the structure

3.1.24
(quasi) static loads
loads independent of time or which vary slowly, so that the dynamic response of the structure is not significant

NOTE (Quasi) static loads comprise both static and dynamic loads and are applied at a frequency sufficiently below the natural frequency of the considered part thus being equivalent to static loads for the structure.

3.1.25
stiffness
ratio between an applied force and the resulting displacement

3.1.26
structure
physical part carrying loads or supporting or protecting other components

NOTE The structure is usually split into primary and secondary structures.

3.1.27
transient load
deterministic load whose magnitude or direction varies with time and for which the dynamic response of the structure is significant

3.1.28
ultimate load
design load multiplied by the ultimate safety factor

3.1.29
ultimate strength
strength of a material in tension, compression, or shear, respectively, which is the maximum tensile, compressive, or shear stress that the material can sustain

NOTE It is implied that the condition of stress represents uniaxial tension, uniaxial compression, or pure shear.

3.1.30
ultimate stress
engineering stress caused by the ultimate load

NOTE With this definition no relation exists with ultimate strength.

3.1.31
yield load
design load multiplied by the yield safety factor

3.1.32
yield strength
stress at which a material exhibits a specified permanent deformation or set

NOTE The permanent deformation is usually determined by measuring the departure of the actual stress-strain diagram from an extension of the initial straight proportion. The specified value is often taken as a unit strain of 0,002.

3.1.33
yield stress
stress caused by the yield load

3.2 Abbreviated terms

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

Abbreviation	Meaning
AIT	assembly, integration and tests
BIT	built-in testing
CAD	computer aided design
CAE	computer aided engineering
CAM	computer aided manufacturing
COG	centre of gravity
COV	coefficient of variation
DoF	degree of freedom
ECLS	environment control and life support
EMC	electromagnetic compatibility

FCI	fracture critical item
FEA	finite element analysis
FE	finite element
FM	flight model
FMECA	failure mode, effects and criticality analysis
FOS	factor of safety
FSI	fluid structure interaction
LCDA	launcher coupled dynamic analysis
MDP	maximum design pressure
MOI	moment of inertia
MOS	margin of safety
NDT	non-destructive test
NDI	non-destructive inspection
PFCI	potential fracture critical item
PFO	particle fall out
r.m.s.	root-mean-square
SM	structural model

4 Requirements

4.1 General

Structural design shall:

a) aim for simple load paths;

b) maximize the use of conventional materials;

c) simplify interfaces;

d) provide easy integration.

4.2 Mission

4.2.1 Lifetime

a) All structural assemblies and components shall be designed to withstand applied loads due to the natural and induced environments to which they are exposed during the service-life and shall be able, in operation, to fulfil the mission objectives for the specified duration.

b) The service-life shall be defined taking into account all ground operations, such as transportation, handling, testing and storage as well as all phases of pre-launch, launch, operation and descent.

c) The phases, applicable loads and duration shall be determined based on:

1) the requirements of the structure (i.e. single mission, expendable, re-usable or long-term deployment),

2) the effect of all degradation mechanisms upon materials used in the construction (i.e. both terrestrial and space environments and all expected loading regimes), and

3) experience with similar structures (e.g. qualification and problems identified in-service).

d) Service-life evaluations shall be applied to determine:

1) the inspection and maintenance requirements,

2) when an item should be replaced (preventive maintenance), and

3) the inspection and repair procedures and intervals (corrective maintenance).

e) An envelope-lifetime, consisting of the most unfavourable sequence of events (loading cycles and thermal cycles) to which the structure can be subjected during its defined service-life, shall be defined as follows:

1) It shall commence at the start of manufacturing and shall end with the completion of the mission;

2) The envelope-lifetime shall be an envelope of all real lifetimes. If there are several variants in the real lifetime, the most severe shall be retained;

3) The envelope-lifetime shall define all lifetime phases and their chronology;

4) For each lifetime phase, the envelope shall take into account the maximum duration and the maximum number of cycles.

4.2.2 Natural and induced environment

a) Components and assemblies for space applications shall be compatible with:

1) the operational environment conditions, and

2) with the atmospheric conditions on earth in which they are manufactured and tested;

b) Consideration shall be given to effects of gravitation and exposure of sensitive materials to manufacturing and atmospheric environments;

c) Provisions (e.g. gravitational compensation and purging) shall be made for the protection of sensitive equipment or components.

NOTE 1 The sensitivity of materials to the environment on earth can determine the requirements for quality control procedures.

NOTE 2 The natural environment generally covers the climatic, thermal, chemical and vacuum conditions, cleanliness, levels of radiation and the meteoroid and space debris environment.

NOTE 3 The induced environments cover the mechanical loads induced by ground handling and pre-launch operations, launch, manoeuvres and disturbances, re-entry, descent and landing. Additional induced environments include static pressure within the payload volume, temperature and thermal flux variations and the electromagnetic and humidity environments.

4.2.3 Mechanical environment

a) The mechanical environment shall be defined by static and dynamic environment loads.

b) The static and dynamic environment loads shall be defined in terms of constant acceleration, transient, sinusoidal and random vibration, acoustic noise and shock loads.

c) All loads shall be considered in the worst combinations in which they occur.

NOTE The severest loads are experienced during launch, ascent and separation, and, where relevant during re-entry, descent and landing.

d) Consideration shall be given to the other loads which can effect the performance in an operational mode.

4.2.4 Microgravity, audible noise and human vibration

Structural requirements dictated by microgravity, audible noise and human vibration system level requirements shall be taken into account.

4.2.5 Corrosion effects

a) The selection of a material for corrosion resistance shall take into account the specific environment, the design and fabrication of individual and assembled components, compatibility of dissimilar materials, susceptibility to fretting and crack initiation.

NOTE Corrosion can be regarded as any deterioration in the physical and chemical properties of a material due to the chemical environment.

b) In cases where the behaviour of a material in a specific environment is not known, corrosion tests of representative materials (composition and condition) shall be performed, either under appropriate service conditions, or in more severe conditions (accelerated testing).

4.2.6 Ablation and pyrolysis

a) The structural design shall take into account the material changes due to ablation and pyrolysis.

b) In cases where an exact prediction of the behaviour of a material in a specific environment is not known, ablation and pyrolysis tests of representative materials (composition and condition) shall be performed, either under appropriate service conditions, or in more severe conditions (accelerated testing).

4.2.7 Micrometeoroid and debris collision

a) Pressurized structures, tanks, battery cells, pipes, electronic boxes and other specified equipment shall be protected from micrometeoroid and debris impact in order to prevent the risk of catastrophic failures.

b) The selection and design of material and debris protection systems shall be based on a specified probability of survival.

NOTE The probability of survival is influenced by the probability of impact, critical debris size, material response to hypervelocity impacts, impact face; back face (spalling), mission duration,spacecraft orientation and multiple impacts.

4.2.8 Venting and purging

a) Provision shall be made in the design of the structure for venting in order to avoid a build-up of excess pressure and to reduce the time to evacuate the structure.

b) In cases where venting is not provided, the structure shall withstand build-up pressure without violating other requirements such as strength or stability.

c) The openings for venting (e.g. to prevent contamination or risk of explosion) shall be compatible with the purging system gas supply pressure and flow rate.

4.2.9 Mass and inertia properties

Mass and inertia properties of the structure shall be determined during all phases of the design applying estimation, calculation or measurement techniques.

NOTE The mass and inertia properties of a structure comprise its mass, the location of its centre of gravity, its moments and products of inertia, and its balancing masses.