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Space systems — Structural components and assemblies

Systèmes spatiaux — Composants et assemblages de structure

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Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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ISO 10786 was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

Introduction

Structures are the backbones of all spaceflight systems. A structural failure could cause the loss of human lives for manned space systems or could jeopardize the intended mission for unmanned space systems. Currently, there is no International Standard that covers all the aspects that can be used for spaceflight structural items such as spacecraft platforms, interstage adaptors, launch vehicle buses and rocket motor cases.

The purpose of this International Standard is to establish general requirements for structures. It provides the uniform requirements necessary to minimize the duplication of effort and the differences between approaches taken by the participating nations and their commercial space communities in developing structures. In addition, the use of agreed-upon standards will facilitate cooperation and communication among space progammes.

Space systems — Structural components and assemblies

1 Scope

This International Standard establishes requirements for the design; material selection and characterization; fabrication; testing and inspection of all structural items in space systems, including expendable and reusable launch vehicles, satellites and their payloads. This International Standard, when implemented for a particular space system, will assure high confidence in achieving safe and reliable operation in all phases of its planned mission.

This International Standard applies specifically to all structural items, including fracture-critical hardware used in space systems during all phases of the mission, with the following exceptions: adaptive structures, engines and thermal protection systems.

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.

ISO 14622:2000, *Space systems —Structural design — Loads and induced environment*

ISO 14623:2003, *Space systems — Pressure vessels and pressurized structures — Design and operation*

ISO 14953:2000, *Space systems — Structural design — Determination of loading levels for static qualification testing of launch vehicles*

ISO 14954:2005, *Space systems — Dynamic and static analysis — Exchange of mathematical models*

ISO 15864:2004, *Space systems — General test methods for space craft, subsystems and units*

ISO 16454:2007, *Space systems — Structural design — Stress analysis requirements*

ISO 21347:2005, *Space systems — Fracture and damage control*

ISO 21648:2008, *Space systems – Flywheel module design and testing*

ISO 22010:2007, *Space systems — Mass properties control*

ISO 24638:2008, *Space systems — Pressure components and pressure system integration*

ISO 24917:2010, *Space systems — General test requirements for launch vehicles*

MIL-STD-1540, *Revision D Test Requirements for Space Vehicles*

3 Terms and definitions

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

3.1
A-basis allowable
A-basis design allowable
A-value
mechanical strength value above which at least 99 % of the population of values is expected to fall, with a confidence level of 95 %

[ISO 16454:2007]

3.2
acceptance test
required formal test conducted on flight hardware to ascertain that the materials, manufacturing processes, and workmanship meet specifications and that the hardware is acceptable for intended usage

[ISO 14623:2003]

3.3
adaptive structures
autonomous structural systems which incorporate sensors, processors, and actuators to enable adaptation to changing environmental conditions, thereby enhancing safety, stability, vibration damping, acoustic noise suppression, aerodynamic performance and optimization, pointing accuracy, load redistribution, damage response, structural integrity, etc.

3.4
allowable load
maximum load that can be accommodated by a structure or a component of a structural assembly without potential rupture, collapse, or detrimental deformation in a given environment

NOTE 1 "Allowable loads" commonly correspond to the statistically based ultimate strength, buckling strength, and yield strength, or maximum strain (for ductile materials).

NOTE 2 "Allowable load" is often referred to as just "allowable".

3.5
assembly
combination of parts, components and units which forms a functional entity

3.6
B-basis allowable
B-basis design allowable
B-value
mechanical strength value above which at least 90 % of the population of values is expected to fall, with a confidence level of 95 %

[ISO 16454:2007]

3.7
buckling
failure mode in which an infinitesimal increase in the load could lead to sudden collapse or detrimental deformation of a structure

EXAMPLE Snapping of slender beams, columns, struts and thin-wall shells.

3.8
catastrophic failure
failure which results in the loss of human life, mission or a major ground facility, or long-term detrimental environmental effects

3.9
collapse
failure mode induced by quasi-static loads (compression, shear or combined stress) accompanied by irreversible loss of load-carrying capability

3.10
composite material
combination of materials different in composition or form on a macro scale

NOTE 1 The constituents retain their identities in the composite.

NOTE 2 The constituents can normally be physically identified, and there is an interface between them.

[ISO 16454:2007]

EXAMPLE Composites include

— fibrous (composed of fibres, usually in a matrix),

— laminar (layers of materials), and

— hybrid (combination of fibrous and laminar).

3.11
composite overwrapped pressure vessel
COPV
pressure vessel with a fibre-based composite system fully or partially encapsulating a liner

NOTE The liner serves as a liquid or gas permeation barrier and may or may not carry substantial pressure loads. The composite overwraps generally carry pressure and environmental loads.

[ISO 14623:2003]

3.12
composite structure
structural components that are made of composite materials

3.13
damage tolerance
ability of a structure or a component of a structural assembly to resist failure due to the presence of flaws, cracks, or other damage for a specified period of unrepaired usage

[ISO 21347:2005]

3.14
design parameter
physical feature which influences the design performance of the design of structural items

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, etc.;

— shape optimization;

— material selection;

— structural topology.

3.15
design safety factor
factor by which limit loads are multiplied in order to account for uncertainties and variations that cannot be analysed or accounted for explicitly in a rational manner

NOTE Design safety factor is sometimes referred to as design factor of safety, factor of safety or just safety factor.

3.16
detrimental deformation
structural deformation, deflection or displacement that prevents any portion of the structure or some other system from performing its intended function or that jeopardizes mission success

3.17
development test
test to provide information that can be used to check the validity of analytic techniques and assumed design parameters, uncover unexpected system response characteristics, evaluate design changes, determine interface compatibility, prove qualification and acceptance procedures and techniques, check manufacturing technology, or establish accept/reject criteria

[ISO 16454:2007]

3.18
dynamic load
time-dependent load with deterministic or stochastic variation

3.19
failure mode

rupture, collapse, detrimental deformation, excessive wear or any other phenomenon resulting in an inability to sustain loads, pressures and corresponding environments, or that jeopardizes mission success

NOTE This definition applies to structural failure.

3.20
fail-safe structure
structural item for which it can be shown by analysis or test that, as a result of structural redundancy, the structure remaining after the failure of any element of the structural item can sustain the redistributed limit load, with an ultimate safety factor of 1,0

[ISO 21347:2005]

3.21
fatigue life
number of cycles of stress or strain of a specified character that a given structure or component of a structural assembly can sustain (without the presence of flaw) before failure of a specified nature could occur

3.22
failure mode effects and critically analysis
FMECA
analysis performed to systematically evaluate the potential effect of each functional or hardware failure on mission success, personnel and system safety, system performance, maintainability and maintenance requirements

NOTE It is also used to rank by the severity of its effect.

3.23
flaw
local discontinuity in a structural material

EXAMPLES Crack, cut, scratch, void, delamination disbond, impact damage and other kinds of mechanical damage.

[ISO 21347:2005]

3.24
fracture control
application of design philosophy, analysis methods, manufacturing technology, verification methodology, quality assurance, including non-destructive evaluation (NDE) and operating procedures to prevent premature structural failure caused by the presence and/or propagation of flaws during fabrication, testing, transportation, handling, and service events such as launch, in-orbit operation, and return

3.25
fracture-critical item
fracture-critical part
structural part whose failure due to the presence of a flaw would result in a catastrophic failure

3.26
full scale article
full-size test article which represents the whole flight structure or a part of the flight structure with representative loading and boundary conditions

3.27
hydrogen embrittlement
mechanical-environmental process that results from the initial presence or absorption of excessive amounts of hydrogen in metals, usually in combination with residual or applied tensile stresses

[ISO 14623:2003]

3.28
human vibration

vibration transmitted to and/or induced by the crew members

3.29
life factor

coefficient by which the number of cycles or time is multiplied in order to account for uncertainties in the statistical distribution of loads and cycles, as well as uncertainties of the methodology used in the life related analyses

NOTE 1 Life factor and scatter factor are interchangeable terms in some documents.

NOTE 2 Life factor is sometimes referred to as scatter factor when uncertainties are material uncertainties.

EXAMPLE Factors used in fatigue (life) analysis and damage tolerance life (crack growth safe-life) analysis.

3.30
limit load
LL
maximum expected load, or combination of loads, which a structure or a component in a structural assembly is expected to experience during its service life in association with the applicable operating environments

NOTE 1 Load is a generic term for thermal load, pressure, external mechanical load (force, moment, or enforced displacement) or internal mechanical load (residual stress, pretension, or inertial load).

NOTE 2 The corresponding stress or strain is called limit stress or limit strain.

NOTE 3 Limit load is sometimes referred to as design limit load. See informative Annex A.

3.31
loading case
combined loading case
particular condition of single (or combined) mechanical load, pressure and temperature, which can occur for some structural components or a structural assembly at the same time during their service life

3.32
loading spectrum
representation of the cumulative loading levels and associated cycles anticipated for the structure or component of a structural assembly according to its service life under all expected operating environments

NOTE Significant transportation, test, and handling loads are included in this definition.

3.33
margin of safety
MS
measure of a structure's predicted reserve strength in excess of the design criteria

NOTE 1 For a single loading condition, MS is expressed as:

MS = { [Allowable Load (Yield or Ultimate)] / [Limit Load x Factor of Safety (Yield or Ultimate)]} -1

NOTE 2 Load may mean force, stress, or strain, if the load-stress relationship is linear.

NOTE 3 The relation also can be expressed for a combined loading case, when the load-stress relationship remains linear for all the contributors of the loading case. Also see alternative methods in Annex D.

3.34
mass and inertia properties
mass and inertia properties of a structure comprise its mass, the location of its centre of gravity, its moments and products of inertia, and, where applicable, its balancing masses

3.35
maximum expected operating pressure
MEOP
highest differential pressure which a pressurized hardware item is expected to experience during its service life and retain its functionality, in association with its applicable operating environments

NOTE 1 MEOP includes the effects of temperature, transient peaks, relief pressures, regulator pressure, vehicle acceleration, phase changes, transient pressure excursions, and relief valve tolerance.

NOTE 2 Some particular project may replace MEOP by Maximum Design Pressure (MDP), which takes into account more conservative conditions.

3.36
metallic structural item
structural item made of metals

NOTE In this document, load bearing metallic liners of COPVs are also referred to as metallic structural items.

3.37
moving mechanical assembly
MMA
mechanical or electromechanical device that controls the movement of one mechanical part of a vehicle relative to another part

EXAMPLES Gimbals, actuators, despin and separation mechanisms, motors, latches, clutch springs, dampers, or bearings.

3.38
POGO
instability due to the coupling between the vehicle axial motion and the dynamic response characteristic of the propulsion system

3.39
pressure component
component in a pressurized system, other than a pressure vessel, pressurized structure that is designed largely by the internal pressure

[ISO 24638:2008]

EXAMPLES Valves, pumps, lines, fittings, hoses and bellows.

3.40
pressure vessel
container designed primarily for storage of pressurized fluid that (1) contains gas or liquid with an energy level of 19,310 joules (14,240 foot-pounds) or greater, based on adiabatic expansion of a perfect gas; or (2) contains gas or liquid that will create a mishap (accident) if released; or (3) will experience a MEOP greater than 700 kPa (100 psi)

NOTE Pressurized structures, pressure components and pressurized equipment are excluded from this definition.

3.41
pressurized equipment
special pressurized equipment
piece of equipment that meets the pressure vessel definition, but for which it is not feasible or cost effective to comply with the requirements applicable to pressure vessels

EXAMPLES Batteries, heat pipes, cryostats and sealed containers.

3.42
pressurized hardware
pressurized hardware includes pressure vessels, pressurized structures, pressure components and pressurized equipment

3.43
pressurized structure
structure designed to carry both internal pressure and vehicle structural loads

[ISO 14623:2003], [ISO 24638:2008]

EXAMPLES Main propellant tanks and solid rocket motor cases of launch vehicles, and crew cabins of manned modules.

3.44
primary structure
part of a structure that carries the main flight loads and defines the overall stiffness of the structure, thus influencing its natural frequencies and mode shapes

3.45
proof factor
multiplying factor applied to the limit load or MEOP to obtain proof load or proof pressure for use in the acceptance testing

3.46
protoqualification test
test of the flight-quality article to a higher load level and duration than the acceptance test applied to flight units under prototype qualification strategy

NOTE The testing consists of the same types and sequences as used in qualification testing.

3.47
qualification test
required formal contractual test conducted at load levels and durations to demonstrate that the design, manufacturing, and assembly of flight-quality structures have resulted in hardware that conforms to specification requirements

NOTE In addition, the qualification test may validate the planned acceptance progamme including test techniques, procedures, equipment, instrumentation, and software.

3.48
random load
vibrating load or fluctuating 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 A random load contains non-periodic or quasi-periodic constituents.

3.49
residual strength
maximum value of load and/or pressure (stress) that a flawed or damaged structural item is capable of sustaining without further damage or collapse, considering appropriate environmental conditions

3.50
residual stress
stress that remains in a structure after processing, fabrication, assembly, testing or operation

EXAMPLE Welding-induced residual stress.

[ISO 14623:2003]

3.51
S-basis allowable
mechanical strength value specified as a minimum by the governing industrial specification, or a particular contractor's specification

EXAMPLES Properties given in MMPDS (Metallic Materials Properties Development and Standardization).

3.52
safe life
(1) design criterion under which failure does not occur in the expected environment during the service life

(2) required period during which a structural item, even containing the largest undetected flaw, is shown by analysis or testing not to fail catastrophically under the expected service load and environment

NOTE 1 An equivalent definition is “period during which the structure is predicted not to fail in the expected service life environment”.

NOTE 2 Safe life is also referred as damage tolerance life or fatigue life.

3.53
safe-life structure
structure designed according to the safe-life design criterion

3.54
scatter factor
coefficient by which the number of cycles or time defined in service life is multiplied in order to account for uncertainties in material properties when performing fatigue and/or crack growth analysis

NOTE Scatter factor is sometimes referred to as life factor, which is usually used for just the difference in material data used in the analysis; for example, S-N data used in fatigue life analysis, or da/dN data used in crack grow analysis.

3.55
secondary structure
structure attached to the primary structure with negligible participation in the main load transfer and overall stiffness

3.56
service life
period of time (or cycles) that starts with item inspection after manufacturing and continues through all testing, handling storage, transportation, launch operations, orbital operations, refurbishment, retesting, re-entry or recovery from orbit, and reuse that can be required or specified for the item

3.57
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

3.58
stiffness
ratio between an applied force and the resulting displacement

3.59
stress-corrosion cracking
mechanically and environmentally induced failure process in which sustained stress and chemical attack combine to initiate and/or propagate a crack or a crack-like flaw in a metal part

[ISO 21347:2005]

3.60
stress-rupture life
minimum time during which a non-metallic structural item maintains structural integrity, considering the combined effects of stress level(s), time at stress level(s), and associated environments

3.61
structural component
mechanical part(s) in a functional hardware item designed to sustain load and/or pressure or maintain alignment

EXAMPLES Antenna support structure, instrument housing, and pressure vessel.

3.62
structural design
process used to determine geometries/dimensions and to select materials of a structure

3.63
structural item
structure, structural subsystem (assembly), or structural component

EXAMPLES Spacecraft trusses, launch vehicle fairings, pressure vessels and pressurized structures; also fasteners, instrument housing and support brackets.

3.64
structural mathematical model
analytical or numerical representation of a structure

NOTE It is advisable that the model provides an adequate description of the structure's response under loads/pressures/temperatures.

[ISO 16454:2007]