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Space systems — Structural design — Stress analysis requirements

Systèmes spatiaux — Conception des structures — Exigences relatives à l'analyse des contraintes

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Foreword

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

This second edition cancels and replaces the first edition (ISO 16454:2007), which has been technically revised.

The main changes are as follows:

— updated the terms and definitions;

— updated requirements in Clause 4.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

From the beginning of the space age, structural integrity verification has been one of the main fields of activity of experts in the domain of mechanics. Mission failure and potential danger to human life, expensive ground constructions and other public and private properties are the most probable consequences of a space structural integrity failure. Static strength is one of the most important critical conditions for structural integrity analysis. It is usually the main criterion for space structure weight evaluation. If the space structure is too heavy, the mission can be extremely expensive or impossible to achieve. If the space structure is under-designed, it can result in mission failure, structural failure, leading to high risk associated with safety of life, and loss of expensive hardware and other properties. It is therefore necessary to specify unique requirements for static strength analysis in order to provide cost-effective design and light-weight, reliable and low-risk structures for space application.

Space systems — Structural design — Stress analysis requirements

1 Scope

This document provides requirements for the determination of maximum stress and corresponding margin of safety under loading and defines criteria for static strength failure modes, such as rupture, collapse and detrimental yielding. This document does not cover critical-conditions-induced fatigue, creep and crack growths. Notwithstanding these limitations in scope, the results of stress calculations based on the requirements of this document are applicable to other critical condition analysis.

This document is applicable to the determination of the stress/strain distribution and margins of safety in launch vehicles and spacecraft load-bearing elements design. Liquid propellant engine structures, solid propellant engine nozzles and the solid propellant itself are not covered, but liquid propellant tanks, pressure vessels and solid propellant cases are within the scope of this document.

In accordance with the requirements of this document, the models, methods and procedures for stress calculation can also be applicable to the displacements and deformation calculation, as well as the calculation of loads, applied to substructures and structural elements under consideration. When this document is applied, it is assumed that temperature distribution has been determined and is used as input data.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

3 Terms and definitions

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

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

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

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

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

3.2
allowable load
allowable stress
allowable strain
maximum *load* (3.18) that can be accommodated by a material or *structure* (3.31) without potential *rupture* (3.25), *collapse* (3.5) or *detrimental yielding* (3.12) in a given environment

Note 1 to entry: The load can imply the corresponding stress or strain.

Note 2 to entry: Allowable loads commonly correspond to the statistically based minimum ultimate strength, buckling strength and yield strength, respectively.

Note 3 to entry: The allowable load shall be determined in accordance with the criteria formulated in 4.6 and the requirements of 4.2.

3.3
basic data
input data required to perform *stress analysis* (3.30) and to determine margins of safety

3.4
B-basis allowable
mechanical strength value above which at least 90 % of the population of values is expected to fall, with a confidence level of 95 %

3.5
collapse
failure mode induced by quasi-static compression, shear or combined stress, accompanied by very rapid irreversible loss of *load* (3.18) resistance capability

3.6
composite material
combination of materials different in composition or form on a macro scale

Note 1 to entry: The constituents retain their identities in the composite.

Note 2 to entry: The constituents can normally be physically identified; and there is an interface between them.

3.7
creep
process of a permanent material deformation resulting from long duration under constant or slowly altered *load* (3.18)

Note 1 to entry: The ultimate creep deformation, corresponding to the loss of material integrity, is often much larger than the ultimate deformation in the case of short time loading.

3.8
critical condition
most severe environmental condition in terms of *load* (3.18) and temperature, or combination thereof, imposed on a *structure* (3.31), system, subsystem or component during its service life

3.9
critical location
structural point at which *rupture* (3.25), *local buckling* (3.20) or *detrimental yielding* (3.12) first leads to structural failure

3.10
design safety factor
coefficient by which *limit loads* (3.17) are multiplied in order to account for the statistical variations of *loads* (3.18) and *structure* (3.31) resistance, and inaccuracies in the knowledge of their statistical distributions

3.11
destabilizing load
load (3.18) that produces compressive stress at *critical location* (3.9)

3.12
detrimental yielding
⟨metallic structures⟩ permanent deformation specified at the system level to be detrimental

3.13
development test
test to provide design information that can be used to check the validity of analytic technique and assumed design parameters, to uncover unexpected system response characteristics, to evaluate design changes, to determine interface compatibility, to prove qualification and acceptance procedures and techniques, to check manufacturing technology, or to establish accept/reject criteria

3.14
flight-type hardware test
test of a flight *structure* (3.31) article, a protoflight model, a representative special model or a structural element fabricated with the same or close to flight hardware technology

3.15
gauge
thickness or other *structure* (3.31) dimension that affects stress levels and/or *margin of safety* (3.21) significantly

3.16
knockdown coefficient
empirical coefficient, other than *design safety factor* (3.10), used to determine analytically actual or *allowable loads* (3.2), as well as allowable stresses or strains, and defined on the basis of test results of flight-type *structures* (3.31), model structures or structural elements as compared with corresponding *stress analysis* (3.30) data

3.17
limit load
maximum *load* (3.18) that can be expected during life cycle of the *structure* (3.31)

3.18
load
volume force or moment, concentrated and/or distributed over the *structure* (3.31) surfaces or structure, caused by its interaction with environment and adjacent parts of vehicle, and accelerations

Note 1 to entry: This includes *pressure* (3.23), external load and enforced displacement acted at considered structural element, pretension, inertial load caused by accelerations and thermal gradient.

3.19
loading case
particular condition described in terms of *loads* (3.18), pressures and temperatures combinations, which can occur for some parts of *structure* (3.31) at the same time during its service life

3.20
local buckling
failure mode that occurs when an alternative equilibrium mode of a structural element exists and can lead to *detrimental yielding* (3.12) or *rupture* (3.25) of that element

Note 1 to entry: Local buckling is not considered as a *critical condition* (3.8) if the *structure* (3.31) can be operated normally during and after loading.

3.21
margin of safety
M_S

$$M_S = \left[\frac{L_A}{(f \times L_L)} \right] - 1$$

where

L_A is the *allowable load* (3.2) under specified functional conditions [e.g. yield, *rupture* (3.25), *collapse* (3.5), *local buckling* (3.20)];

L_L is the *limit load* (3.17);

f is the *design safety factor* (3.10)

Note 1 to entry: Load can imply corresponding stress or strain.

3.22
minimum allowable
minimum material mechanical properties warranted by the supplier

3.23
pressure
external *load* (3.18) caused by fluid action on a structural surface

Note 1 to entry: The terms "pressure" and "load" are sometimes referred to simultaneously in this document.

3.24
primary structure
part of a vehicle that carries the main *loads* (3.18) and/or defines the fundamental resonance frequencies

3.25
rupture
loss of integrity by *structure* (3.31) material differed from fatigue and ultimate *creep* (3.7) deformation attainment, which can prevent the structure from withstanding *load* (3.18) combinations

3.26
semi-finished item
product that is used for *structure* (3.31) manufacturing or assembling

EXAMPLE Sheets, plates, profiles, strips.

3.27
stabilizing load
load (3.18) which decreases compressive stresses if applied in conjunction with *destabilizing loads* (3.11)

3.28
static strength
property of a *structure* (3.31), characterized by its capability to withstand *loads* (3.18) and temperature combinations without *rupture* (3.25), *collapse* (3.5), detrimental *local buckling* (3.20) and *detrimental yielding* (3.12)

3.29
strength failure mode
condition of a *structure* (3.31) or a structural element considered as a *critical condition* (3.8) in accordance with *stress analysis* (3.30) results

3.30
stress analysis
analytical procedure to determine structure stress or strain distribution, deformations and margins of safety

3.31
structure
primary structure (3.24), *unit* (3.34) attachments, *pressure* (3.23) or *loads* (3.18) carrying elements of pressure vessels, loads carrying elements of appendages (solar panels and antennas)