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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

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 16454 was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

Introduction

From the beginning of the space age, structural integrity verification has been one of the main fields of mechanical specialists' activity. Mission failure and potential danger to human life, expensive ground constructions and other public and private property are the most probable consequences in the case of space structural integrity failure. Static strength is one of the most important critical conditions for structural integrity analysis. It is usually the main criteria for space structure weight evaluation. If the space structure is too heavy, the mission could be extremely expensive or impossible to achieve. If the space structure is underdesigned, it could result in structural failure, leading to high risk associated with safety of life, and loss of expensive hardware and other property. 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.

The analysis and design of space structures has a long history. This International Standard establishes the preferred requirements related to these techniques for static strength critical condition.

Space systems — Structural design — Stress analysis requirements

1 Scope

This International Standard is intended to be used for the determination of the stress/strain distribution and margins of safety in launch vehicles and spacecraft primary structure 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 International Standard.

This International Standard 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. Critical conditions associated with fatigue, creep and crack growths are not covered. Notwithstanding these limitations in scope, the results of stress calculations based on the requirements of this International Standard are applicable to other critical condition analyses.

In accordance with the requirements of this International Standard, models, methods and procedures for stress determination can also be applied to the displacements and deformation calculations, as well as to the loads definition, applied to substructures and structural members of structures under consideration. When this International Standard is applied, it is assumed that temperature distribution has been determined and is used as input data.

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, *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.

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 (stress, strain) that can be accommodated by a material/structure without potential rupture, collapse or detrimental deformation in a given environment

NOTE Allowable loads (stresses, strains) commonly correspond to the statistically based minimum ultimate strength, buckling strength and yield strength, respectively.

3.3
basic data
input data required to perform stress analysis 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 resistance capability

3.6
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.

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

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

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

3.9
critical location
structural point at which rupture, local buckling or detrimental deformation will first lead to structural failure

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

3.11
destabilizing load
load that produces compressive stress at critical location

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 article, a protoflight model, a representative special model or a structural element fabricated with the same or close to flight hardware technology

3.15
gauges
thickness and other structure dimensions which relative scattering could result in significant effect on stress levels and/or margin of safety

3.16
knockdown coefficient
empirical coefficient, other than design safety factor, which is used to determine analytically in a simple way actual or allowable loads or stresses, and which is defined on the basis of test results of flight-type structures, model structures or structural members as compared with corresponding stress analysis data

3.17
limit load
maximum that can be expected during service life and in the presence of the environment

NOTE For stabilizing loads, the limit load is the minimum load.

3.18
loads
volume forces and moments, concentrated and/or distributed over the structure surfaces or structure, caused by its interaction with environment and adjacent parts of vehicle, and accelerations

NOTE This includes pressures, external loads and enforced displacements acted at considered structural element, pretension, inertial loads caused by accelerations and thermal gradients.

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

3.20
local buckling
failure mode, which occurs when an alternative equilibrium mode of a structural member exists, and which could lead to detrimental deformation or rupture of that member if it occurs under loading

3.21
margin of safety
M_S
expression of the margin of the limit load multiplied by design safety factor against the allowed load

Another representation of the concept:

$$M_S = \left(\frac{F_{AL}}{f_{DS} \times F_{LL}} \right) - 1 \qquad (1)$$

where

F_{AL} is the allowable load under specified functional conditions (e.g. yield, rupture, collapse, local buckling);

F_{LL} is the limit load;

f_{DS} is the design safety factor.

NOTE Load can imply corresponding stress or strain.

3.22
minimum allowable
minimum material mechanical properties warranted by the supplier

3.23
pressure
external load caused by fluid action on a structural surface

NOTE The terms "pressure" and "load" are sometimes referred to simultaneously in this International Standard.

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

3.25
rupture
loss of integrity by structure material differed from fatigue and ultimate creep deformation attainment, which could prevent the structure from withstanding load combinations

3.26
semi-finished item
product that is used for structure manufacturing or assembling

EXAMPLE Sheets, plates, profiles, strips, etc.

3.27
stabilizing load
load which decreases compressive stresses if applied in conjunction with destabilizing loads

3.28
static strength
property of a structure, characterized by its capability to withstand loads and temperature combinations without rupture, collapse, detrimental local buckling and detrimental deformation

3.29
strength failure mode
condition of a structure or a structural member considered as a critical condition in accordance with stress analysis results

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

3.31
structure
primary structure, unit attachments, pressure/loads carrying elements of pressure vessels, loads carrying elements of appendages

3.32
structural mathematical model
analytical or digital presentation of a structure

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

3.33
ultimate load
limit load multiplied by ultimate design safety factor

3.34
unit
part of a vehicle which is designed mainly to provide vehicle functioning and which differs from a structure

