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Space systems — Structural design — Determination of loading levels for static qualification testing of launch vehicles

Systèmes spatiaux — Conception des structures — Détermination des niveaux de chargement pour un essai statique de qualification des véhicules lanceurs

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Foreword

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International Standard ISO 14953 was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

Space systems — Structural design — Determination of loading levels for static qualification of launch vehicles

1 Scope

This International Standard specifies a procedure for determining the loading level of a qualification test of a launch vehicle structure and takes into account all the minimum allowable strength characteristics necessary for these structures.

This International Standard establishes the required resistance necessary for all mass-produced items to comply with product assurance criteria.

2 Terms and definitions

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

2.1
external mechanical loading
system of forces and moments external to a structure and brought to bear on that structure

2.2
safety factor
J
coefficient by which a limit load is multiplied

2.2.1
yield strength safety factor
J_E
ratio of the yield load of the material to the limit load

NOTE This coefficient is applicable only to metal structures.

2.2.2
ultimate safety factor
J_R
ratio of the allowable ultimate load to the limit load

2.3
overload
excess of internal distributed load used for certain calculations to account for design

3 Design of loading levels

3.1 General

Qualification tests shall be conducted on a flight-type structure. Because such structures are unlikely to include minimum values for all allowable characteristics, the loads used for design shall be corrected before use in qualification tests. All areas of the launch-vehicle flight structure shown to be critical in probable failure modes shall be considered for the following correction which shall be used to determine qualification test loading.

3.2 Calculation of qualification test loading

The corrected external loading, P_Q, (force, moment, pressure) used for qualification tests shall be calculated from the following equation:

$$P_Q = P_{lim} \times J_C$$

where

P_{lim} is the external loading limit corresponding to the of the highest stress combination of external loads likely to occur simultaneously while in service (value used for design);

J_C is the corrected safety factor (see 3.3).

3.3 Corrected safety factor

The corrected factor, J_C, is given by the following equation:

$$J_C = \frac{J \times K_{min} \times K_{adj} + K_T}{K_\theta \times K_\sigma}$$

where:

J is the safety factor used for design (either for yield or for ultimate conditions);

K_{min} is the correction factor for thickness (see 3.4.1);

K_{adj} is the correction factor for adjacent structures (see 3.4.2);

K_T is the correction factor for thermal gradients (see 3.4.3);

K_θ is the correction factor for temperature (see 3.4.4);

K_σ is the correction factor for the moduli (see 3.4.5).

3.4 Correction factors

3.4.1 Correction factor for thickness, K_{min}

This factor takes into account the influence of the minimum thickness on the structure resistance; it is defined as the ratio of the thickness of the test specimen to the minimum allowable manufacturing thickness.

This correction factor is applicable only to metal structures. For other structures, use $K_{min} = 1$.

3.4.2 Correction factor for adjacent structures, K_{adj}

3.4.2.1 Generally speaking during static qualification tests, the influence of adjacent structures should be simulated. In this case, take $K_{adj} = 1$.

3.4.2.2 When the influence of adjacent structures cannot be simulated correctly by the test facility, use a correction factor K_{adj}. The authority in charge of the structure shall deduce this factor by comparing results of two calculations made from the theoretical model.

3.4.2.3 Make the first calculation using boundary conditions of the test configuration and yields and for each area, determine the stress σ_{test}.

3.4.2.4 Make the second calculation using boundary conditions of the flight configuration and yields and determine the stress σ_{flight}.

In both calculations, the configuration shall include the local stiffness of interfaces without overload.

3.4.2.5 The factor K_{adj} is determined by:

$$K_{\text{adj}} = \frac{\sigma_{\text{flight}}}{\sigma_{\text{test}}} \times K_{\text{overload}}$$

where K_{overload} is the overload factor used for design $\geqslant 1$.

If, as a result $K_{\text{adj}} < 1$, use $K_{\text{adj}} = 1$.

3.4.3 Correction factor for thermal gradients, K_T

This factor is the ratio of the increase in stress resulting from the effect of the local thermal gradient to the stress corresponding to a zero thermal gradient.

3.4.4 Correction factor for temperature, K_θ

This factor takes into account the effect of temperature on the characteristics of the material; it is defined as the ratio of the value of the characteristic considered at the operating temperature of the flight structure to its value at the test temperature:

$$K_\theta = \frac{C_{\theta,\text{ flight}}}{C_{\theta,\text{ test}}}$$

where

$C_{\theta,\text{flight}}$ is a characteristic at the operating temperature;

$C_{\theta,\text{test}}$ is a characteristic at the test temperature.

3.4.5 Correction factor for the moduli, K_σ

This factor takes into account the effect of Young's modulus, allowable stresses, and geometry on the wrinkling strength, compression strength, and tensile strength of the structure at the ambient temperature. For a characteristic C_i acting in a given failure mode:

$$K_\sigma = \frac{f\,(C_{i,\text{ min}})}{f\,(C_{i,\text{ test}})}$$

where

$C_{i,\text{min}}$ is the minimum allowable value of the characteristic C_i at ambient temperature (20 °C);

$C_{i,\text{test}}$ is the value of characteristic C_i for the specimen subjected to the test at 20 °C;

$f(C_i)$ is the function which translates the effect of the given characteristics in the failure mode considered.

EXAMPLE: $f(C_1) = C_1^2$, if the structure strength is proportional to the square of C_1 in the failure mode considered.

If several characteristics C_1, C_2, ..., C_n, act in the failure mode considered, they will give the following equation:

$$K_\sigma = \frac{f(C_{1,\text{min}})}{f(C_{1,\text{test}})} \times \frac{f(C_{2,\text{min}})}{f(C_{2,\text{test}})} \times \cdots \times \frac{f(C_{n,\text{min}})}{f(C_{n,\text{test}})}$$

NOTE With metal structures, the minimum thickness is the minimum allowable manufacturing thickness.

3.5 Comparison of results

If the results of calculations of stress made for test conditions are significantly different from those made for flight conditions or if the corrected safety factor, J_C, reaches a non-credible value, other specific modes of tests and correction of design loads, i.e. other than those proposed in this International Standard, may be used if they have been already established, justified and previously used.

3.6 Implementation of this International Standard

The corrected external loading shall be determined for all the areas of the flight-type structure considered as critical according to calculations in view of probable failure modes.

The lowest value of P_Q shall be selected for qualification tests.

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