SLOVENSKI STANDARD

SIST EN 16603-32-11:2014

01-november-2014

Vesoljska tehnika - Ocenjevanje modalnega pregleda

Space engineering - Modal survey assessment

Raumfahrttechnik - Modale Prüfungsbewertung

Ingénierie spatiale - Evaluation des modes vibratoires

Ta slovenski standard je istoveten z: EN 16603-32-11:2014

ICS:

49.140	Vesoljski sistemi in operacije	Space systems and operations

SIST EN 16603-32-11:2014 **en,fr,de**

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 16603-32-11

August 2014

ICS 49.140

English version

Space engineering - Modal survey assessment

Ingénierie spatiale - Evaluation des modes vibratoires

Raumfahrttechnik - Modale Prüfungsbewertung

This European Standard was approved by CEN on 23 February 2014.

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Ref. No. EN 16603-32-11:2014 E

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Foreword

This document (EN 16603-32-11:2014) has been prepared by Technical Committee CEN/CLC/TC 5 “Space”, the secretariat of which is held by DIN.

This standard (EN 16603-32-11:2014) originates from ECSS-E-ST-32-11C.

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of an identical text or by endorsement, at the latest by February 2015, and conflicting national standards shall be withdrawn at the latest by February 2015.

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1
Scope

This Standard specifies the basic requirements to be imposed on the performance and assessment of modal survey tests in space programmes. It defines the terminology for the activities involved and includes provisions for the requirement implementation.

This Standard specifies the tasks to be performed when preparing, executing and evaluating a modal survey test, in order to ensure that the objectives of the test are satisfied and valid data is obtained to identify the dynamic characteristics of the test article.

This standard may be tailored for the specific characteristics and constrains of a space project in conformance with ECSS-S-ST-00.

2
Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this ECSS Standard. For dated references, subsequent amendments to, or revision of any of these publications, do not apply. However, parties to agreements based on this ECSS Standard are encouraged to investigate the possibility of applying the more recent editions of the normative documents indicated below. For undated references, the latest edition of the publication referred to applies.

EN reference	Reference in text	Title
EN 16601-00-01	ECSS-S-ST-00-01	ECSS system — Glossary of terms
EN 16603-10-03	ECSS-E-ST-10-03	Space engineering — Testing
EN 16603-32	ECSS-E-ST-32	Space engineering — Structural general requirements

3
Terms, definitions and abbreviated terms

3.1 Terms from other standards

For the purpose of this Standard, the terms and definitions from ECSS-S-ST-00-01 apply.

3.2 Terms specific to the present standard

3.2.1 accelerance

ratio of the output acceleration spectrum to the input force spectrum

NOTE 1 **Accelerance** is computed as follows:

$$A(\omega) = \frac{\ddot{X}(\omega)}{F(\omega)}$$

where

$\ddot{X}(\omega)$ is the output acceleration spectrum;

$F(\omega)$ is the input force spectrum.

NOTE 2 The **accelerance** is also called “inertance” and it is the inverse of the **apparent mass** (see 3.2.2).

3.2.2 apparent mass

ratio of the input force spectrum to the output acceleration spectrum

NOTE 1 **Apparent mass** is computed as follows:

$$M(\omega) = \frac{F(\omega)}{\ddot{X}(\omega)}$$

where

$F(\omega)$ is the input force spectrum;

$\ddot{X}(\omega)$ is the output acceleration spectrum.

NOTE 2 The **apparent mass** is also called “dynamic mass”, and it is the inverse of the **accelerance** (see 3.2.1).

3.2.3 auto modal assurance criterion
AutoMAC

measure of the degree of correlation between two **mode shape**s of the same **mode shape** set

NOTE 1 For example, test **mode shape**s or analysis **mode shape**s.

NOTE 2 The **AutoMAC** is a specific case of the **MAC** (see 3.2.26); the **AutoMAC** matrix is symmetric.

NOTE 3 The **AutoMAC** is particularly useful for assessing whether a given selection of DOFs is adequate for **MAC** evaluations employing two different sets of **mode shape**s (e.g. test and analysis).

3.2.4 coherence function

measure of the degree of linear, noise-free relationship between the measured system input and output signals at each frequency

NOTE 1 The **coherence function** is defined as

$$\gamma^2(\omega) = \frac{\left|S_{xf}(\omega)\right|}{S_{xx}(\omega)\, S_{ff}(\omega)}$$

where

ω	is the frequency;
$S_{ff}(\omega)$	is the power spectrum of the input signal;
$S_{xx}(\omega)$	is the power spectrum of the output signal;
$S_{xf}(\omega)$	is the input-output cross spectrum.

NOTE 2 $\gamma^2(\omega)=1$ indicates a linear, noise-free relationship between input and output.

NOTE 3 $\gamma^2(\omega)=0$ indicates a non causal relationship between input and output.

3.2.5 complex mode shape

modal vector of a non-proportionally damped system

NOTE 1 For **complex mode shape**s, any phase relationship can exits between different parts of the structure.

NOTE 2 **Complex mode shape**s can be considered to be propagating waves with no stationary node lines.

3.2.6 complex mode indicator function

indicator of the existence of real or complex modes and their relative magnitudes

NOTE **The complex mode indicator function** has extended functionality to estimate approximate **modal parameters**.

3.2.7 co-ordinate modal assurance criterion
CoMAC

measure of the correlation of the a given DOF of two different sets of **mode shape**s over a number of comparable-paired **mode shape**s

NOTE 1 The coordinate **modal assurance criterion** for DOF *j* is defined as:

$$CoMAC(j) = \frac{\left[\sum_{r=1}^{m} \left|\Phi_{jr}^{X} \Phi_{jr}^{A}\right|\right]^2}{\sum_{r=1}^{m} \left(\Phi_{jr}^{X}\right)^2 \sum_{r=1}^{m} \left(\Phi_{jr}^{A}\right)^2}$$

where

Φ_{jr}^{A} is the **mode shape** coefficient for DOF *j* for mode *r* of set *A*;

Φ_{jr}^{X} is the **mode shape** coefficient for DOF *j* for mode *r* of set *X*;

r is the index of the correlated mode pairs.

For example, **mode shape**s *X* and *A* are test and analysis **mode shapes**, respectively.

NOTE 2 **CoMAC** = 1 indicates perfect correlation.

NOTE 3 The results can be considered to be meaningful only when the **CoMAC** is applied to matched modes, i.e. for correlated mode pairs.

3.2.8 damping

dissipation of oscillatory or vibratory energy with motion or with time

3.2.9 damped natural frequency

frequency of **free vibration**s of a damped linear mechanical system

3.2.10 driving point residue

calculated quantity that defines the most appropriate exciter positions

NOTE The magnitude of the **driving point residue** for a location is defined as:

$$\left|r_{jr}\right| = \frac{v_{jr}^2}{2 m_r \omega_{dr}}$$

where

r_{jr} is the **driving point residue** of DOF *j* for mode *r*;

v_{jr} is the **mode shape** coefficient of DOF *j* for mode *r*;

m_r is the modal mass for mode *r*;

ω_{dr} is the damped natural frequency for mode *r*.

3.2.11 dynamic compliance

ratio of the output displacement spectrum to the input force spectrum

NOTE 1 **Dynamic compliance** is computed as follows:

$$H(\omega) = \frac{X(\omega)}{F(\omega)}$$

where

$X(\omega)$ is the output displacement spectrum;

$F(\omega)$ is the input force spectrum.

NOTE 2 The **dynamic compliance** is also called dynamic flexibility, and it is the inverse of the **dynamic stiffness** (see 3.2.12).

3.2.12 dynamic stiffness

ratio of the input force spectrum to the output displacement spectrum

NOTE 1 **Dynamic stiffness** is computed as follows:

$$K(\omega) = \frac{F(\omega)}{X(\omega)}$$

where

$F(\omega)$ is the input force spectrum;

$X(\omega)$ is the output displacement spectrum.

NOTE 2 The **dynamic stiffness** is the inverse of the **dynamic compliance** (see 3.2.11).

3.2.13 effective modal mass

measure of the mass portion associated to the **mode shape** with respect to a reference support point

NOTE 1 The six effective masses for a normal mode, $\{\Phi\}_r$, are the diagonal values of the modal mass matrix.

$$[M]_r = \frac{\{L\}_r^T \{L\}_r}{m_r}$$

where

$\{L\}_r$ is the **modal participation factor**:

$$\{L\}_r = \{\Phi_{RB}\}^T [M] \{\phi\}_r \ ;$$

m_r is the generalised mass:

$$m_r = \{\Phi\}_r^T [m] \{\phi\}_r \ ;$$

$\{\Phi\}_r$, is the elastic mode r;

$\{\Phi_{PB}\}$, is the rigid body mode.

NOTE 2 The sum of the effective masses provides an indication of the completeness of the measured modes, since the accumulated effective mass contributions from all modes equal the total structural mass and inertia for each of the six translatory and rotatory DOFs, respectively.

3.2.14 eigenfrequency

See **natural frequency**

3.2.15 finite element model
FEM

mathematical representation of a physical structure or system where the distributed physical properties are represented by a discrete model consisting of a finite number of idealized elements which are interconnected at a finite number of nodal points

NOTE The **FEM** contains only a finite number of degrees of freedom compared to the infinite number of degrees of freedom for the physical structure or system.

3.2.16 forced vibration

vibratory motion of a system that is caused by mechanical excitation

3.2.17 free vibration

vibratory motion of a system without forcing

3.2.18 frequency response assurance criterion
FRAC

measure of the similarity between an analytical and experimental **frequency response function**

NOTE 1 The **frequency response assurance criterion** is a degree of freedom correlation tool. It is the **FRF** equivalent to the **CoMAC** (see 3.2.7).

NOTE 2 The frequency response assurance criterion is defined as

$$FRAC(j,k) = \frac{\left| \left\{ {}_X H_{jk}(\omega) \right\}^T \left\{ {}_A H_{jk}(\omega) \right\} \right|^2}{\left(\left\{ {}_X H_{jk}(\omega) \right\}^T \left\{ {}_X H_{jk}(\omega) \right\} \right) \left(\left\{ {}_A H_{jk}(\omega) \right\}^T \left\{ {}_A H_{jk}(\omega) \right\} \right)}$$

where

$_A H_{jk}(\omega)$ is the analytical **frequency response function** of a **response** at DOF j due to an excitation at DOF k;

$_X H_{jk}(\omega)$ is the corresponding experimental **frequency response function**.

NOTE 3 **FRAC** = 1 indicates a perfect correlation of the two **frequency response functions**.

NOTE 4 **FRAC** = 0 indicates a non correlation of the two **frequency response functions**.

3.2.19 frequency response function
FRF

descriptor of a **linear system** in the frequency domain that relates the output motion spectrum (displacement, velocity or acceleration) to the input force spectrum

NOTE 1 The **frequency response function** is generally defined as:

$$H(\omega) = \frac{X(\omega)}{F(\omega)}$$

NOTE 2 $H(\omega)$ is a complex function containing magnitude and phase information.

NOTE 3 Common definitions of standard and inverse **FRF** are:

- accelerance or inertance (see 3.2.1);
- apparent or dynamic mass (see 3.2.2);
- dynamic compliance or flexibility (see 3.2.11);
- dynamic stiffness (see 3.2.12).
- **impedance** (see 3.2.22);
- **mobility** (see 3.2.24).

3.2.20 fundamental resonance

first major significant **resonance** as observed during the modal survey test

NOTE 1 For unconstrained mechanical systems, the **fundamental resonance** is the lowest **natural frequency** with motions of the whole test article.

NOTE 2 For clamped mechanical systems, the **fundamental resonance** is the mode with the largest effective mass.

3.2.21 impact

single collision between masses where at least one of the masses is in motion

3.2.22 impedance

ratio of the input force spectrum to the output velocity spectrum

NOTE 1 **Impedance** is computed as follows:

$$Z(\omega) = \frac{F(\omega)}{\dot{X}(\omega)}$$

where

$F(\omega)$ is the input force spectrum;

$\dot{X}(\omega)$ is the output velocity spectrum.

NOTE 2 The **impedance** is the inverse of the **mobility** (see 3.2.24).

3.2.23 linear system

system whose response is directly proportional to the excitation for every part of the system

3.2.24 mobility

ratio of the output velocity spectrum to the input force spectrum