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Flight dynamics — Concepts, quantities and symbols —

Part 9:
Models of atmospheric motions along the trajectory of the aircraft

Mécanique du vol — Concepts, grandeurs et symboles —

Partie 9: Modèles de mouvements atmosphériques le long de la trajectoire de l'avion

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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.

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.

International Standard ISO 1151-9 was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Sub-Committee SC 3, *Concepts, quantities and symbols for flight dynamics*.

ISO 1151 consists of the following parts, under the general title *Flight dynamics — Concepts, quantities and symbols*:

— *Part 1: Aircraft motion relative to the air*

— *Part 2: Motions of the aircraft and the atmosphere relative to the Earth*

— *Part 3: Derivatives of forces, moments and their coefficients*

— *Part 4: Concepts, quantities and symbols used in the study of aircraft stability and control*

— *Part 5: Quantities used in measurements*

— *Part 6: Aircraft geometry*

— *Part 7: Flight points and flight envelopes*

— *Part 8: Concepts and quantities used in the study of the dynamic behaviour of the aircraft*

— *Part 9: Models of atmospheric motions along the trajectory of the aircraft*

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ISO 1151 is intended to introduce the main concepts, to include the more important terms used in theoretical and experimental studies and, as far as possible, to give corresponding symbols.

In all the parts comprising ISO 1151, the term "aircraft" denotes a vehicle intended for atmosphere or space flight. Usually, it has an essentially port and starboard symmetry with respect to a plane. That plane is determined by the geometric characteristics of the aircraft. In that plane, two orthogonal directions are defined: fore-and-aft and dorsal-ventral. The transverse direction, on the perpendicular to that plane, follows.

When there is a single plane of symmetry, it is the reference plane of the aircraft. When there is more than one plane of symmetry, or when there is none, it is necessary to choose a reference plane. In the former case, the reference plane is one of the planes of symmetry. In the latter case, the reference plane is arbitrary. In all cases, it is necessary to specify the choice made.

Angles of rotation, angular velocities and moments about any axis are positive clockwise when viewed in the positive direction of that axis.

All the axis systems used are three-dimensional, orthogonal and right-handed, which implies that a positive rotation through $\pi/2$ around the x-axis brings the y-axis into the position previously occupied by the z-axis.

The centre of gravity coincides with the centre of mass if the field of gravity is homogeneous. If this is not the case, the centre of gravity can be replaced by the centre of mass in the definitions of ISO 1151; in which case, this should be indicated.

Numbering of sections and clauses

With the aim of easing the indication of references from a section or a clause, a decimal numbering system has been adopted such that the first figure is the number of the part of ISO 1151 considered.

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Flight dynamics — Concepts, quantities and symbols —

Part 9:
Models of atmospheric motions along the trajectory of the aircraft

9.0 Introduction

This part of ISO 1151 deals with the concepts and quantities characterizing models of the air motions affecting the dynamic behaviour of the aircraft.

The motion of the air with respect to the Earth is defined by the wind velocity (2.2.3) in each point of the aircraft trajectory (8.2.1).

In flight dynamic problems, it is usual to use mathematical models of the wind velocity field and its variations with time. These are schematic representations of the real air motions.

In this part of ISO 1151, the following models are defined:

— constant wind (9.1);

— wind gradients (9.2);

— discrete gusts (9.3);

— three-dimensional wind models (9.4);

— vortices (9.5).

Other models can be defined by superposition of these models.

9.1 Constant wind

No.	Term	Definition	Symbol
9.1.1	Steady wind	Wind model defined such that the wind velocity (2.2.3) is constant with time.	—
9.1.2	Constant wind	Wind model defined such that the wind velocity (2.2.3) is constant with time and equal at each point in a considered space. NOTE — This is the wind model used in other parts of ISO 1151.	—
9.1.3	Mean wind velocity	Constant wind (9.1.2) defined conventionally in models that include variations of air motion with time. $\overline{\vec{V}_W} = \frac{1}{T}\int_0^T \vec{V}_W \, dt$ where $\vec{V}_W$ is the wind velocity (2.2.3); T is the length of the considered time interval. NOTE — In wind models characterized by wind velocity variations only with time, the mean wind is the same in each point along the considered trajectory.	$\overline{\vec{V}_W}$

9.2 Wind gradients

No.	Term	Definition	Symbol
9.2.1	Wind gradient	Wind model in which the variations of the wind velocity — are equal to zero with respect to time, and — are continuous functions of the coordinates with respect to the normal earth-fixed axis system (1.1.2). In this case, the variation $\Delta \vec{V}_W$ of the wind velocity with respect to these coordinates is given by: $\Delta \vec{V}_{W0} = \begin{pmatrix} \Delta u_{W0} \\ \Delta v_{W0} \\ \Delta w_{W0} \end{pmatrix} = \begin{pmatrix} u_{Wx} & u_{Wy} & u_{Wz} \\ v_{Wx} & v_{Wy} & v_{Wz} \\ w_{Wx} & w_{Wy} & w_{Wz} \end{pmatrix} \begin{pmatrix} \Delta x_0 \\ \Delta y_0 \\ \Delta z_0 \end{pmatrix}$ where $u_{Wx} = \frac{\partial u_{W0}}{\partial x_0}, \; u_{Wy} = \frac{\partial u_{W0}}{\partial y_0}$, etc. and $\Delta x_0, \Delta y_0, \Delta z_0$ are the variations of the coordinates.	—
9.2.2	Constant wind gradient	Wind model in which the wind gradient (9.2.1) is the same at each point in a considered space.	—

9.3 Discrete gusts

9.3.1 General description of gusts

No.	Term	Definition	Symbol
9.3.1.1	Gust	Wind model characterized by a deterministic and rapid variation of the wind velocity $\vec{V}_W$ (2.2.3) causing a variation of the air velocity $\vec{V}$ (1.3.1).	—
9.3.1.2	Gust velocity Gust speed	Component of the wind velocity $\vec{V}_W$ (2.2.3) attributed to the gust (9.3.1.1). Magnitude of the gust velocity.	$\vec{V}_G$ V_G
9.3.1.3	Gust profile	Function of distance on the aircraft trajectory (8.2.1), or of time characterizing the gust velocity (9.3.1.2) in a gust model. NOTE — The gust profile is characterized by: — an initial value zero of the gust velocity; — the characteristic gust speed (9.3.1.4); — the direction of the gust; — the final value of the gust velocity.	—
9.3.1.4	Characteristic gust speed	Maximum value of the gust speed (9.3.1.2) in the gust model.	—
9.3.1.5	Characteristic gust length	Shortest distance on the aircraft trajectory (8.2.1) corresponding to a variation of wind speed V_W (2.2.3) equal to the characteristic gust speed (9.3.1.4).	l_G
9.3.1.6	Longitudinal gust	Gust profile (9.3.1.3) in which only the component of the gust velocity (9.3.1.2) with respect to the air-path axis x_a (1.1.6) is different from zero. NOTE — A longitudinal gust can also be defined using the component with respect to the longitudinal axis (1.1.5).	—
9.3.1.7	Lateral gust	Gust profile (9.3.1.3) in which only the component of the gust velocity (9.3.1.2) with respect to the lateral air-path axis y_a (1.1.6) is different from zero. NOTE — A transverse gust can be defined using the component with respect to the transverse axis (1.1.5).	—
9.3.1.8	Normal gust	Gust profile (9.3.1.3) in which only the component of the gust velocity (9.3.1.2) with respect to the normal air-path axis z_a (1.1.6) is different from zero. NOTE — A normal gust can also been defined using the component with respect to the normal axis (1.1.5).	—
9.3.1.9	Vertical gust	Gust profile (9.3.1.3) in which only the component of the gust velocity (9.3.1.2) with respect to the vertical axis z_o (1.1.2) is different from zero.	—
9.3.1.10	Horizontal gust	Gust profile (9.3.1.3) in which only the component of the gust velocity (9.3.1.2) with respect to an axis fixed in the horizontal plane $x_o y_o$ (1.1.2) is different from zero. NOTE — In this case, the direction of the axis with respect to the normal earth-fixed axis system (1.1.2) should be specified.	—

9.3.2 Standard gusts

In studies of the dynamic response of aircraft to atmospheric disturbances, various standard gust profiles (9.3.1.3) are used. Other gust profiles can be defined on the basis of the standard gust profiles listed below.

In the following clauses, the following symbols are used:

a constant value

i alphanumeric subscript characterizing the considered atmospheric disturbance

t_0 initial instant of the atmospheric disturbance

Δt characteristic time interval

All the standard gust profiles are zero for $t < t_0$.

If $t_0 = 0$, reference to the initial instant may be omitted from the symbol.

The characteristic time interval, Δt, can be omitted from the symbol if it is clearly defined.

No.	Term	Definition	Symbol
9.3.2.1	Step gust	Gust model in which the component of the gust velocity (9.3.1.2) along the considered axis varies as a step function (8.5.1) with respect to time: $$\Gamma_{Gi}(t_0) = \begin{cases} 0 & \text{if } t < t_0 \\ a & \text{if } t \geq t_0 \end{cases}$$	$\Gamma_{Gi}(t_0)$
9.3.2.2	Ramp gust	Gust model in which the component of the gust velocity (9.3.1.2) along the considered axis varies as a limited ramp function (8.5.3) with respect to time: $$\rho_{Gi}(t_0, \Delta t) = \begin{cases} 0 & \text{if } t < t_0 \\ a\dfrac{t - t_0}{\Delta t} & \text{if } t_0 \leq t \leq t_0 + \Delta t \\ a & \text{if } t > t_0 + \Delta t \end{cases}$$	$\rho_{Gi}(t_0, \Delta t)$
9.3.2.3	(1 – cos) step gust	Gust model in which the component of the gust velocity (9.3.1.2) along the considered axis varies with respect to time according to the law: $$\Psi_{Gi}(t_0, \Delta t) = \begin{cases} 0 & \text{if } t < t_0 \\ \dfrac{a}{2}\left(1 - \cos\dfrac{\pi(t - t_0)}{\Delta t}\right) & \text{if } t_0 \leq t \leq t_0 + \Delta t \\ a & \text{if } t > t_0 + \Delta t \end{cases}$$	$\Psi_{Gi}(t_0, \Delta t)$
9.3.2.4	(1 – cos) pulse gust	Gust model in which the component of the gust velocity (9.3.1.2) along the considered axis varies with respect to time according to the law: $$\Omega_{Gi}(t_0, \Delta t) = \begin{cases} 0 & \text{if } t < t_0 \\ \dfrac{a}{2}\left(1 - \cos\dfrac{2\pi(t - t_0)}{\Delta t}\right) & \text{if } t_0 \leq t \leq t_0 + \Delta t \\ 0 & \text{if } t > t_0 + \Delta t \end{cases}$$	$\Omega_{Gi}(t_0, \Delta t)$

9.4 Three-dimensional wind models

No.	Term	Definition	Symbol
9.4.1	Discontinuous wind shear	Wind model defined by the juxtaposition of two constant winds (9.1.2) on the two sides of a plane, with different velocity vectors parallel to that plane. NOTES 1 This concept implies necessarily the existence of a discontinuity across the separating plane. 2 In crossing the separating plane, the aircraft is subject to a change in wind velocity as in a step gust (9.3.2.1). 3 It is possible to replace the separating plane by a thin layer in which the wind gradient (9.2.1) is large but limited.	—
9.4.2	Downburst	Three-dimensional wind model characterized by: — a cylindrical symmetry with respect to a vertical axis, — high downward wind speed. NOTE — The wind velocity is essentially vertical in the upper part of a downburst and horizontal near the ground.	—

9.5 Vortices

No.	Term	Definition	Symbol
9.5.1	Vortex	Wind model characterized by the rotation of the air about an axis.	—
9.5.2	Rankine vortex model	Vortex (9.5.1) model in which the local air velocities are contained in planes normal to the vortex axis and are tangential to circles centred on this axis. The speed of the air at a distance r from the vortex axis is: $V_V = V_n \hat{r}$ for $\hat{r} \leq 1$ and $V_V = \frac{V_n}{\hat{r}}$ for $\hat{r} \geq 1$ with $\hat{r} = \frac{r}{r_n}$ where r_n is the radius of the vortex core; V_n is the tangential speed of the air for $r = r_n$ NOTE — In the Rankine model, the air inside the core rotates at identical angular speeds.	—
9.5.3	Empirical vortex model	Vortex (9.5.1) model in which the local air velocities are contained in planes normal to the vortex axis and are tangential to circles centred on this axis. The speed on the air at a distance r from the vortex axis is: $V_V = V_n \frac{2\hat{r}}{1+\hat{r}^2}$ with $\hat{r} = \frac{r}{r_n}$ where r_n is the radius of the vortex core; V_n is the tangential speed of the air for $r = r_n$	—