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Rotorcrafts – Flight dynamics – Vocabulary

Giravions – Dynamique de vol – Vocabulaire

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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 8, *Aerospace terminology*.

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Rotorcrafts – Flight dynamics – Vocabulary

1 Scope

This document defines terms used in the field of rotorcrafts flight dynamics and aerodynamics, for example, rotorcraft design documents, with regard to rotorcrafts geometry and dynamic characteristics.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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 Basic definitions and classification

3.1.1
rotorcraft
rotary wing aircraft
heavier-than-air aircraft that depends principally for its support in flight on the aerodynamical generated by one or more rotors

3.1.2
helicopter
rotorcraft (3.1.1) that primarily depends on engine driven rotors for motion at all stage of flight

3.1.3
gyroplane
autogyro
gyrocopter
rotaplane
rotorcraft (3.1.1) whose rotors are not engine-driven, except for initial starting, but are made to rotate by action of the air when the rotorcraft is moving; and whose means of propulsion, consisting usually of conventional propellers, is independent of the rotor system

3.1.4
gyrodyne
compound helicopter
compound gyroplane
rotorcraft (3.1.1) with a rotor system that is normally driven by its engine for takeoff, hovering and landing like a *helicopter* (3.1.2), and has an additional propulsion system that is independent of the rotor system

3.1.5
convertiplane
aircraft which uses rotor power for vertical takeoff and landing (vtol) and converts to fixed-wing lift in normal flight

Note 1 to entry: Convertiplanes may be divided into two broad classes, based on whether the rotor is fixed as in a *helicopter* (3.1.2) or tilts to provide thrust in forward flight, as a proprotor. a proprotor may be in a tilt rotor or tilt wing configuration.

3.1.6
tiltrotor aircraft
rotorcraft (3.1.1) which generates lift and propulsion by way of one or more tiltable (rotating) powered propellers, or proprotors, mounted on rotating engine pods or nacelles usually at the ends of a fixed wing

Note 1 to entry: Orientation of wings is fixed. For vertical flight, the rotors are angled so the plane of rotation is horizontal.

3.1.7
tiltwing aircraft
aircraft with a wing that is horizontal for conventional forward flight and rotates up for vertical takeoff and landing

3.1.8
helicopter configuration
combination of features, defining *main rotor* (3.2.1) system, anti-torque system (for *single rotor helicopter* (3.1.9)), flight control system

3.1.9
single rotor helicopter
helicopter (3.1.2) with one (main) rotor that provides lift and propulsive force

Note 1 to entry: Single rotor helicopters may be divides into four or more types depending of anti-torque system:

— with *tail rotor* (3.2.2) (classic configuration);

— with *fenestrone* (3.2.25);

— with *notar* (3.2.26) (no tail rotor) system;

— *tip jets* (3.2.24) (no anti-torque system required).

3.1.10
dual rotor helicopter
twin-rotor helicopter
helicopter (3.1.2) with two counter-rotating *main rotors* (3.2.1) rotors

3.1.11
tandem rotors helicopter
dual rotor helicopter (3.1.10) with two horizontal *main rotors* (3.2.1) assemblies mounted one behind the other

3.1.12
side-by-side rotors
transverse rotors helicopter
dual rotor helicopter (3.1.10) with a set of counter-rotating *main rotors* (3.2.1) assemblies which are located in the same plane side-by-side on the *helicopter* (3.1.2) and where the *stagger* (3.5.15) is greater than the diameter of the disk

3.1.13
coaxial rotors helicopter
dual rotor helicopter (3.1.10) with a pair of counter-rotating *main rotors* (3.2.1) mounted one above the other on the same shaft and turning in opposite directions

3.1.14
intermeshing rotors helicopter
synchropter
dual rotor helicopter (3.1.10) with a set of two counter-rotating *main rotors* (3.2.1) with each rotor mast mounted on the *helicopter* (3.1.2) with a slight angle to the other so that the *blades* (3.2.5) intermesh without colliding

3.1.15
multicopter
multirotor
rotorcraft (3.1.1) with more than two rotors that provide lift

3.1.16
quadcopter
quadrocopter
quadrotor
multicopter (3.1.15) that is lifted and propelled by four rotors

3.1.17
hexacopter
multicopter (3.1.15) that is lifted and propelled by six rotors

3.1.18
octocopter
multicopter (3.1.15) that is lifted and propelled by eight rotors

3.2   Basic elements

3.2.1
main rotor
combination of a rotary wing and a control system that generates the aerodynamic lift force that supports the weight of the *helicopter* (3.1.2), and the thrust that counteracts aerodynamic drag in forward flight

3.2.2
tail rotor
smaller rotor mounted so that it rotates vertically or near-vertically at the end of the tail of a traditional *single rotor helicopter* (3.1.9) to compensate *main rotor* (3.2.1) torque moment

3.2.3
main rotor hub
toe unit for the rotor *blades* (3.2.5) attachment to rotor shaft

Note 1 to entry: The hub is located at the top of the mast.

3.2.4
hinge
mechanism that holds the *blades* (3.2.5) proper to the hub and allows free angular motion with zero moment transfer

3.2.5
blade
main working unit of rotor working as rotating wing which provides lift due to rotation about rotor shaft axis

3.2.6
horizontal hinge
flapping hinge
hinge (3.2.4) which allows the *blade* (3.2.5) to move up and down with respect to the plane of rotor rotation

Note 1 to entry: This movement is called flapping.

3.2.7
vertical hinge
lead-lag hinge
drag hinge
hinge (3.2.4) which allows the *blade* (3.2.5) to move back and forth in the plane of rotor rotation

Note 1 to entry: This movement is called lead-lag, dragging, or hunting.

3.2.8
axial hinge
feathering hinge
hinge (3.2.4) along the *feathering* (3.2.32) axis of *blade* (3.2.5) that allows to change the pitch of rotor blades due to pilot input to the collective or cyclic control

3.2.9
articulated rotor
rotor system with each *blade* (3.2.5) attached to the rotor hub through a series of *hinges* (3.2.4) (horizontal and (or) vertical) that let the blade move independently of the others

3.2.10
fully articulated rotor
rotor system with each *blade* (3.2.5) attached to the rotor hub through a series of *hinges* (3.2.4) (horizontal and vertical) that let the blade move independently of the others

Note 1 to entry: The blades in this case are allowed to flap, and lead or lag independently of each other.

3.2.11
hingeless rotor
rotor with no actual mechanical *hinges* (3.2.4) that achieves flapping and lead-lag motion by elastically flexing

3.2.12
rotor with separated hinges
rotor system for which the distances of *horizontal hinge* (3.2.6) from the rotor hub isn't equal to zero

3.2.13
rotor with joined hinges
fully articulated rotor (3.2.10) system for which the *horizontal hinge* (3.2.6) and *vertical hinge* (3.2.7) are located at the same distances from the rotor hub

3.2.14
rigid rotor
rotor system in which the *blades* (3.2.5) accommodate flapping and lead-lag motions by bending the elastic elements at the corner part of blade without *horizontal hinge* (3.2.6) and *vertical hinge* (3.2.7)

3.2.15
semirigid rotor
teetering
seesaw
rotor system normally composed of two *blades* (3.2.5) that meet just under a common flapping or teetering *hinge* (3.2.4) perpendicular to rotor shaft axis and mounted at the top of rotor shaft

3.2.16
semi-articulated rotor
rotor in which the *blade* (3.2.5) is attached to hub by two *hinges* (3.2.4) instead of three (without *horizontal hinge* (3.2.6) or *vertical hinge* (3.2.7))

3.2.17
rotor head with universal joint
gimballed rotor hub tilts with respect to the rotor shaft to accommodate *blade* (3.2.5) flapping or which tilts the blades (rotor disk) creating a force that pulls the autogiro in the direction of the tilt

3.2.18
swashplate
device that translates input via the *helicopter* (3.1.2) flight controls into motion of the *main rotor* (3.2.1) *blades* (3.2.5)

Note 1 to entry: A swashplate is used to transmit three of the pilot's commands from the non-rotating fuselage to the rotating rotor hub and main rotor blades.

3.2.19
blade element
spanwise piece of the *blade* (3.2.5)

Note 1 to entry: A blade element has a spanwise dimension of any length (usually an elementary spanwise length).

3.2.20
blade tip
part of rotor *blade* (3.2.5) which is the most distant from rotor axis

3.2.21
blade root
part of the *blade* (3.2.5) that attaches to the *blade grip* (3.2.22)

3.2.22
blade grip
blade fork
part of the hub assembly to which the rotor *blades* (3.2.5) are attached

3.2.23
external point of rotor blade
crossing point of *rotor blade axis* (3.3.9) with the plane tangential to surface of *blade tip* (3.2.20) and perpendicular to *blade* (3.2.5) axis

3.2.24
tip jets
rotor system which is driven by jet nozzles at the tip of rotor *blades* (3.2.5) powered by ram-jets, pulse-jets, or rockets or by high pressure air provided by a compressor

3.2.25
fenestrone
fan-in-tail
ducted fan
protected *tail rotor* (3.2.2) of a *helicopter* (3.1.2) operating like a rotor mounted within a cylindrical shroud or duct

3.2.26
notar
air-blowing system to compensate *main rotor* (3.2.1) torque moment

3.2.27
interleaving rotors
two rotor disks which are located in the same horizontal plane and where the *stagger* (3.5.15) is greater than the radius of the disk, but less the diameter of the disk

3.2.28
intermeshing rotors
two rotor disks which are located in different planes and where the *stagger* (3.5.15) is less than the radius of the disk

3.2.29
bearringless rotor
hingeless rotor (3.2.11) wherein the *feathering* (3.2.32) bearing is replaced by a torsionally soft elastic element

3.2.30
advancing blade
blade (3.2.5) moving in the same direction as the *helicopter* (3.1.2)

3.2.31
retreating blade
blade (3.2.5), located in a semicircular part of the rotor disk, in which the blade direction is opposite to the direction of flight

3.2.32
blade feather
feathering
rotation of the *blade* (3.2.5) around the spanwise (pitch change) axis

3.3   Coordinate axis and planes

3.3.1
helicopter body axis coordinate system
right rectangular system of the coordinates which has been rigidly connected with a fuselage. the origin o_1 is the centre of mass of a fuselage

Note 1 to entry: The longitudinal axis (O_1X_1) is directed to a *helicopter* (3.1.2) nose perpendicular to a shaft of the *main rotor* (3.2.1).

Note 2 to entry: The normal axis (Z_1Y_1) is directed parallel to a shaft of the main rotor and points downwards.

Note 3 to entry: The transverse axis (O_1Z_1) is completing system.

3.3.2
longitudinal axis of helicopter body axis
axis (O_1X_1) which is directed to a *helicopter* (3.1.2) nose perpendicular to a shaft of the *main rotor* (3.2.1)

3.3.3
normal axis of helicopter body axis
axis (O_1Y_1) which is directed parallel to a shaft of the *main rotor* (3.2.1) and points downwards

3.3.4
transverse axis of helicopter body axis
axis (O_1Z_1) which completes the system

3.3.5
stability axis coordinate system
hub-wind axis
rectangular coordinate system, with origin in a point of intersection of an axis of rotor rotation with the plane of *main rotor* (3.2.1), having the normal axis (O_hY_h) parallel to axis of the main rotor rotation, directions of longitudinal axis (O_hX_h) and transverse axis (O_hZ_h) are defined by the direction of the air speed vector projection to the plane of rotation of a main rotor

3.3.6
longitudinal axis of stability coordinate system
longitudinal axis (O_hX_h) which is perpendicular to *rotor rotation axis* (3.3.10) and having the same direction as the rotor air speed vector projection to the plane of rotation of a *main rotor* (3.2.1)

3.3.7
normal axis of stability coordinate system
normal axis (O_hY_h) coinciding with the axis of rotor rotation and having opposite direction as direction of lift

3.3.8
transverse axis of stability coordinate system
transverse axis (O_hZ_h) which is perpendicular to the plane formed by (O_hX_h) and (O_hY_h) axis and directed to forward moving *blade* (3.2.5)

3.3.9
rotor blade axis
straight line around which the angular orientation of *blade* (3.2.5) cross-section is changed due to influence of actuator of rotor control system

3.3.10
rotor rotation axis
geometric axis of *main rotor* (3.2.1) shaft or bearing, rotor being rotating around this axis

3.3.11
rotor rotation plane
plane perpendicular to *rotor rotation axis* (3.3.10), forming by rotated *blade* (3.2.5) axis with zero flapping angle

3.3.12
blade rotation plane
plane parallel to the tip path plane through the hub centre

3.3.13
hub plane
plane perpendicular to the shaft axis through the centre of the hub

3.3.14
tip pass plane
TPP
no-flapping plane
plane containing flight path of *blade tips* (3.2.20) at their rotation around shaft axis

3.3.15
tip path axis
disc axis
axis perpendicular to the plane through the *blade tips* (3.2.20) and, for zero offset *horizontal hinges* (3.2.6), which is therefore the axis of no flapping

3.3.16
no-feathering axis
axis relative to which the cyclic *feathering* (3.2.32) vanishes the axis through the centre of the hub and perpendicular to the swash plates

3.3.17
control axis plane
plane of the rotor wherein there is no cyclic *feathering* (3.2.32) (i.e. the plane of the swash plate)

3.3.18
hub axis coordinate system
coordinate system $O_sX_sY_sZ_s$ used to determine the rotor aerodynamic loads and rotor *blades* (3.2.5) flapping due to controls and body angular rates

Note 1 to entry: The origin O_s of axes is at centre of rotor hub. The normal axis (O_sY_s) points downwards and aligns with the rotor shaft. The longitudinal axis (O_sX_s) points toward the nose of *helicopter* (3.1.2) and is perpendicular to axis O_sY_s. The transverse axis (O_sZ_s) points to the right side.

3.3.19
blade section common plane axis system
right rectangular coordinate system, with origin O_{BS} in a point of intersection of *blade* (3.2.5) pitch axis and in-plane blade section

Note 1 to entry: The longitudinal axis ($O_{BS}X_{BS}$), which is in the in-plane blade section, parallel to the formed rotation plane, points to leading edge of blade section *airfoil* (3.5.11). The transverse axis ($O_{BS}Z_{BS}$), which is coincident with blade pitch axis, points to *blade tip* (3.2.20). The normal axis ($O_{BS}Y_{BS}$), which is in the in-plane blade section, points upwards.

3.4 Angles

3.4.1
blade azimuth angle
ψ
angle of *blade* (3.2.5) axis rotation measured in a plane normal to the shaft of the *main rotor* (3.2.1)

Note 1 to entry: Blade azimuth angle is zero when the blade is over the tail.

Note 2 to entry: Blade azimuth angle is positive in the direction of rotation.

Note 3 to entry: ψ_i is the azimuth (angle) of the *i*-th blade.

3.4.2
blade flapping angle
blade flap angle
β
angle between a line drawn along the span of the *blade* (3.2.5) and a plane normal to the shaft axis

Note 1 to entry: Blade flapping angle is positive when the *blade tip* (3.2.20) is higher than the blade cuff.

Note 2 to entry: β_i is the flapping angle of the *i*-th blade.

3.4.3
blade coning
upward sweep of rotor *blades* (3.2.5) as a result of lift and centrifugal force

3.4.4
blade lag-lead angle
ξ
angle of rotation of an axis of the *blade* (3.2.5) around axis of the *vertical hinge* (3.2.7) (or the line equivalent to this axis in case of the blade mounting the elastic unit), measured from the plane passing through the axis of *main rotor* (3.2.1) rotation and an axis of the blade at $\beta = 0$

Note 1 to entry: Blade lag-lead angle is positive in case of the blade axis deviation in the direction opposite to main rotor rotation.

Note 2 to entry: ξ_i is the lead-lag angle of the *i*-th blade.

3.4.5
blade pitch angle
θ
angle between the chord line of the rotor *blade* (3.2.5) and the reference plane of the *main rotor* (3.2.1) hub or the rotor plane of rotation

Note 1 to entry: θ_i is the lead-lag angle of the *i*-th blade.

Note 2 to entry: Blade pitch is positive when the leading edge is up.

3.4.6
rotor angle of attack
α_H
<stability coordinate system> angle between a vector of *main rotor* (3.2.1) air speed and the rotor plane of rotation

Note 1 to entry: Rotor angle of attack is positive if the projection of air speed to a normal axis is negative.

3.4.7
collective pitch angle
longitudinal cyclic pitch angle
lateral cyclic pitch angle
θ_0
θ_{1C}
θ_{1S}
average value and the first harmonic cosine and sine components of *blade pitch angles* (3.4.5) as function of *blade azimuth angle* (3.4.1)

3.4.8
mast angle
α_T
tilt angle calculated with respect to the vertical axis on the ground

3.4.9
angle between rotors axis
inclination of one *main rotor* (3.2.1) shaft with respect to another main rotor shaft for intermeshing and transverse *dual rotor helicopter* (3.1.10)

3.4.10
pitch of the blade element
blade element pitch angle
θ_r
angle between *blade chord* (3.5.9) and rotor plane of rotation (at the radius *r*)

3.4.11
pitch of the main rotor
blade incidence angle
$\theta_{0,7}$
pitch of the blade element (3.4.10) at a *relative radius* (3.5.7) of $\bar{r} = 0,7$

3.4.12
geometric twist of the blade
difference of the *pitch of the blade elements* (3.4.10) of the *main rotor* (3.2.1) with respect to the pitch of the blade element at a *relative radius* (3.5.7) of $\bar{r} = 0,7$

3.4.13
collective pitch
part of a *helicopter's* (3.1.2) control system wherein all *blades* (3.2.5) change pitch simultaneously by the same amount

3.4.14
cyclic pitch
part of a *helicopter's* (3.1.2) control system wherein the *blades* (3.2.5) change pitch in a sinusoidal fashion as they traverse around the rotor azimuth, each blade having the same amount of such pitch change when it reaches any given rotor azimuth

3.5   Geometry

3.5.1
radius of the main rotor
R
radius of the circle swept out by the *blade tips* (3.2.20)

3.5.2
diameter of the main rotor
D
diameter of the circle swept out by the *blade tips* (3.2.20)

Note 1 to entry: $D = 2 * R$.

3.5.3
radius of the tail rotor
R_{TR}
radius of the circle swept out by the *tail rotor* (3.2.2) *blade tips* (3.2.20)

3.5.4
diameter of the tail rotor
D_{TR}
diameter of the circle swept out by the *tail rotor* (3.2.2) *blade tips* (3.2.20)

Note 1 to entry: $D_{TR} = 2 * R_{TR}$.

3.5.5
rotor disk area
F_H
area covered by rotor *blades* (3.2.5) at its rotation at $\beta = \xi = 0$

3.5.6
radius of rotor blade section
r
distance from rotor axis to *blade* (3.2.5) cross-section by plane perpendicular to blade axis at $\beta = \xi = 0$

Note 1 to entry: *r* is the radial location, measured from the centre of rotation ($r = 0$) to the *blade tip* (3.2.20) ($r = R$).

3.5.7
relative radius
$\bar{r}$

ratio of the radius of a *blade element* (3.2.19) to the radius of the rotor ($\bar{r} = \dfrac{r}{R}$)

3.5.8
blade cross-section chord
b
straight line joining the leading edge of *blade* (3.2.5) cross-section with its trailing edge

Note 1 to entry: Blade cross-section at fixed radius is designated by a subscript, for example, $b_{0,7}$ is the blade cross-section at *relative radius* (3.5.7) $\bar{r} = 0{,}7$.

3.5.9
blade chord
blade (3.2.5) width, that is, local dimension perpendicular to blade radius

3.5.10
blade span
length of a *blade* (3.2.5) from its tip to its root

3.5.11
airfoil
shape of a cross-section of a rotor *blade* (3.2.5)

3.5.12
rotor solidity ratio
σ

ratio of the lifting area of the *blades* (3.2.5) to the area of the rotor(s), $\sigma = \dfrac{z_b \cdot b_{0,7}}{\pi \cdot R}$, where z_b is the

number of blades of the rotor

3.5.13
rotor blade horizontal hinge offset
L_g
distance between horizontal *blade* (3.2.5) *hinge* (3.2.4) axis and rotor axis

3.5.14
rotor blade vertical hinge offset
L_v
distance between vertical *blade* (3.2.5) *hinge* (3.2.4) axis and rotor axis

3.5.15
stagger
stagger distance
d_s
horizontal centre-to-centre distance between two rotor disks

Note 1 to entry: It is applicable to intermeshing, interleaving, side-by-side, tandem and quad *helicopters* (3.1.2).

3.5.16
overlap ratio
percentage of the overlapped area to that of the total area of the two rotor disks (for dual rotor interference)

3.5.17
pitch-flap coupling
automatic kinematic pitch change caused by flapping motion, as results from the delta-three *hinge* (3.2.4)

3.5.18
aspect ratio
ratio of the *blade* (3.2.5) radius to the average *blade chord* (3.5.9) length

3.5.19
thickness ratio
ratio of maximum thickness to *airfoil* (3.5.11) chord

3.5.20
taper ratio
ratio of the chord length at the tip of *blade* (3.2.5) to the chord length at the root of blade

3.6 Dynamic characteristic

3.6.1
disc loading
ratio of weight of *helicopter* (3.1.2) to the total *main rotor* (3.2.1) disc area

3.6.2
blade flap and pitch static moments of inertia
S_β
S_ξ
static moment of inertia of *main rotor* (3.2.1) *blade* (3.2.5) and other assembled units, flapping with blade:

— around *horizontal hinge* (3.2.6);

— around *vertical hinge* (3.2.7)

3.6.3
blade flap and pitch moments of inertia
I_β
I_ξ
moment of inertia of *main rotor* (3.2.1) *blade* (3.2.5) and other assembled units, flapping with blade:

— around *horizontal hinge* (3.2.6);

— around *vertical hinge* (3.2.7)

3.6.4
main rotor moment of inertia
I_ω
total inertia moment of all *blades* (3.2.5) and other rotating units, connected with blades, referred to *main rotor* (3.2.1) axis of rotation

3.6.5
lock's inertia number
γ
ratio of the aerodynamic and inertial forces on the aerodynamic and inertial forces acting on an *articulated rotor* (3.2.9) *blade* (3.2.5)

$$\gamma = \frac{\rho \cdot c \cdot a_0 \cdot R^4}{I_\beta}$$

where

a_0 is the derivative of aerodynamics load factor of blade with respect to blade angle of attack;

c is the rotor *blade chord* (3.5.9);

ρ is the air density

3.6.6
main rotor airspeed
v_H
speed of centre O_H of stability system with reference to free air

3.6.7
main rotor speed
rotor RPM
Ω_{MR}
ω_H
angular speed of *main rotor* (3.2.1) rotation around rotor axis with respect to *helicopter* (3.1.2) fuselage

Note 1 to entry: RPM stands for revolution per minute.

3.6.8
blade tip speed
tip speed
average speed of *blade tip* (3.2.20) motion due to rotor rotation at $\beta = \xi = 0$

3.6.9
inflow
downward component of air velocity through and perpendicular to the rotor disk

3.6.10
rotor induced velocity
v_i
increment of the air velocity component along the rotor axis at the rotor disc induced by the lift of the *blades* (3.2.5)

3.6.11
total inflow velocity
sum of the component of *helicopter* (3.1.2) velocity normal to the plane of the rotor disk and induced velocity

$$V_H \cdot \sin\alpha_H + v_i$$

3.6.12
advance ratio
tip speed ratio
μ
non-dimensional forward speed, which is the ratio of component of *helicopter* (3.1.2) velocity in the plane of the rotor disk to rotor *tip speed* (3.6.8)

$$\mu = \frac{V_H \cdot cos\alpha_H}{\Omega_{MR} \cdot R}$$

3.6.13
inflow ratio
λ
ratio of total average velocity normal to the plane of rotation to the *tip speed* (3.6.8), normally taken positive when flowing downward through disk

$$\lambda = \frac{V_H \cdot \sin\alpha_H + v_i}{\Omega_{MR} \cdot R}$$

3.6.14
reverse flow region
area on the retreating side of the rotor disk where the velocity relative to the *blade* (3.2.5) is directed from the trailing edge to the leading edge

Note 1 to entry: The reverse flow boundary is a circle of diameter μ, centred at $r = \mu/2$ on the $\psi = 270°$ radial on the retreating side.

3.6.15
propeller-working state
vertical climb while the rotor disc is moving in the direction of thrust and the airflow is directed downward through the rotor

Note 1 to entry: The limiting condition for the propeller working state is the static-thrust case, or hovering.

3.6.16
vortex ring state
settling with power
power settling
flight condition at the increased rate of descent in which a *helicopter* (3.1.2) that is receiving power from its engine(s) loses *main rotor* (3.2.1) lift (thrust) and subsequently experiences loss of control due to an increased upward flow of air at the rotor tips and an increased upward flow of air at the *blade roots* (3.2.21)

Note 1 to entry: The airflow through the rotor disk recirculates and forms a vertical structure at the *blade tips* (3.2.20).

3.6.17
windmill brake state
condition in which the rotor derives its energy from the air because the flow is upward through the rotor and the slowing of the air as it passes through the rotor disk produces the thrust

Note 1 to entry: The boundary condition between the vortex-ring and windmill-brake states is the condition where the upward flow of air is brought to rest at the rotor disk. This condition of no flow through the disk is referred to as ideal *autorotation* (3.8.13).

3.6.18
hover figure of merit
FOM
rotor hovering efficiency
rotor thrust efficiency
ratio of the minimum possible power required to hover (ideal power obtained from momentum theory) to the actual power required to hover

3.7 Forces and moments

3.7.1
rotor aerodynamic force
R_H
total aerodynamic force acting on *main rotor* (3.2.1)

3.7.2
rotor drag force
H
longitudinal component of *rotor aerodynamic force* (3.7.1) (along the *longitudinal axis of stability coordinate system* (3.3.6)), which is positive rearward

3.7.3
rotor lift force
T
rotor thrust
normal component of *rotor aerodynamic force* (3.7.1) (along the *normal axis of stability coordinate system* (3.3.7)), which is positive upward

3.7.4
rotor side force
S
transverse component of *rotor aerodynamic force* (3.7.1) (along the *transverse axis of stability coordinate system* (3.3.8))

3.7.5
aerodynamic moment of rotor
M_H
total aerodynamic moment acting on *main rotor* (3.2.1)

3.7.6
longitudinal aerodynamic moment of rotor
M_{XH}
component of *rotor aerodynamic force* (3.7.1) along the *transverse axis of stability coordinate system* (3.3.8)

3.7.7
normal aerodynamic moment of rotor
M_{YH}
component of *rotor aerodynamic force* (3.7.1) along the *normal axis of stability coordinate system* (3.3.7)

3.7.8
lateral aerodynamic moment of rotor
M_{ZH}
component of *rotor aerodynamic force* (3.7.1) along the *longitudinal axis of stability coordinate system* (3.3.6)

3.7.9
torque moment of rotor
M_K
component of *rotor aerodynamic force* (3.7.1) along the *normal axis of stability coordinate system* (3.3.7) with negative sign

3.7.10
aerodynamic force coefficient
ratio of aerodynamic forces components along stability coordinate system axis, to value

$$\frac{1}{2}\rho\left(\omega_H R\right)^2 F_H$$

where ρ is the air density

3.7.11
aerodynamic moment coefficient
ratio of aerodynamic moment components along stability coordinate system axis, to value

$$\frac{1}{2}\rho\left(\omega_H R\right)^2 F_H R$$

where ρ is the air density

3.8 Performance

3.8.1
avoid zone
Deadman's curve
height-speed diagram
boundaries of the combinations of altitude and forward speed where it is impossible to demonstrate safe autorotative landings at a vertical touchdown speed within the design limits of the landing gear

3.8.2
ground effect of rotor
beneficial gain in lifting power when operating near the surface, caused by the rotor downwash field being altered from its free air state by the presence of the surface

3.8.3
hover in ground effect
hover at the low altitude (less than rotor diameter) where the downwash of air from the *main rotor* (3.2.1) is able to react with a hard surface (the ground) under the *helicopter* (3.1.2) and give a useful reaction to the helicopter in the form of more lift force available with less engine power required

3.8.4
hover out of ground effect
condition opposite to the in-ground effect (IGE), where there are no hard surfaces under the *helicopter* (3.1.2) for the downwash to react against

3.8.5
parasite power
portion of the power required to move the rest of the airframe through the air

Note 1 to entry: It is the power required to overcome parasite drag.

3.8.6
rotor induced power
portion of the power required to produce lift

Note 1 to entry: Induced power is the force required to move a mass of air through the disk at the induced velocity.

3.8.7
rotor profile power
power required just to turn the rotors

Note 1 to entry: It is the power required to overcome the rotor aerodynamic drag force.

3.8.8
rotor power required
sum of *parasite power* (3.8.5), *rotor induced power* (3.8.6), *rotor profile power* (3.8.7) and miscellaneous power consumers like the *tail rotor* (3.2.2), hydraulic pumps, gearbox losses, generators, etc.

3.8.9
rotor power available
P
power produced by engine(s)

3.8.10
vertical rate of climb
climb speed at vertical (the aircraft's velocity normal to the ground) with zero speed at horizon

3.8.11
best rate of climb
clime speed at which a *helicopter* (3.1.2) obtains the greatest gain in altitude over a given period of time

3.8.12
maximum slung weight
maximum weight of external cargo that can be carried on suspended from the *helicopter* (3.1.2) by means of an external cargo hook or hooks

3.8.13
gliding in autorotation
autorotation
flight idle glide
FIG
condition of flight during which the *main rotor* (3.2.1) is driven only by aerodynamic forces with no power from the engine

3.8.14
autorotation glide slope angle
γ_G
angle determined by the vertical speed and horizontal speed under *autorotation* (3.8.13)

$$\gamma_G = \tan^{-1} \frac{V_{vertical}}{V_{horizontal}}$$

3.9 Flight quality (according to ADS–33-PRF)

3.9.1
mission-task-elements
MTE
selection of precisely defined flight test manoeuvres (operational missions), which provide a basis for an overall assessment of the *rotorcraft's* (3.1.1) ability to perform certain critical tasks, and result in an assigned level of handling quality (HQ)

3.9.2
operational flight envelopes
OFE
boundaries within which the *rotorcraft* (3.1.1) must be capable of operating in order to accomplish the operational missions (MTE)

Note 1 to entry: These envelopes shall be defined in terms of combinations of airspeed, altitude, load factor, rate-of-climb, side-velocity, and any other parameters specified by the system specification, as necessary to accomplish the operational missions.

3.9.3
service flight envelopes
SFE
parameters used to define the *OFEs* (3.9.2), plus any additional parameters deemed necessary to define the appropriate limits where the inner boundaries of the SFEs are defined as coincident with the outer boundaries of the OFEs, and the outer boundaries of the SFEs are defined by one or more of the following: uncommanded *rotorcraft* (3.1.1) motions, or structural, engine/power-train, or rotor system limits

Note 1 to entry: The service flight envelopes shall be derived from rotorcraft limits as distinguished from mission requirements.

3.9.4
rotor RPM governing
criterion of *helicopter* (3.1.2) handling qualities requirements used to demonstrate that the *rotor RPM* (3.6.7) remain within the limits set by the *service flight envelopes* (3.9.3) during the execution of all *mission-task-elements* (3.9.1) conducted within the *operational flight envelopes* (3.9.2)

3.9.5
interaxis coupling
criterion of *helicopter* (3.1.2) handling qualities requirements used to demonstrate that control inputs to achieve a response in one axis doesn't result in objectionable responses in one or more of the other axes

3.9.6
position hold
criterion of *helicopter* (3.1.2) handling qualities requirements used to demonstrate that the *rotorcraft* (3.1.1) can automatically hold its position with respect to a ground fixed or shipboard *hover* (3.1.11) reference

3.9.7
torque response
criterion of *helicopter* (3.1.2) handling qualities requirements used to demonstrate that the torque, or any other parameter displayed to the pilot as a measure of the maximum allowable power that can be commanded without exceeding engine or transmission limits, has dynamic response characteristics that fall within the specified limits

3.9.8
rotor start/stop
criterion of *helicopter* (3.1.2) handling qualities requirements used to demonstrate that it is possible, while on the ground, to start and stop the rotor *blades* (3.2.5) in mean winds up to at least 45 knots from the most critical direction

3.9.9
requirements for externally slung loads: load release
criterion of *helicopter* (3.1.2) handling qualities requirements used to demonstrate that the *rotorcraft* (3.1.1) is capable of safely jettisoning external loads from any condition within the external loads *service flight envelopes* (3.9.3)

3.9.10
requirements for externally slung loads: failure of external load system
criterion of *helicopter* (3.1.2) handling qualities requirements used to demonstrate that any single failure of a suspension system element (including attachment fittings, slings, pendants, apex fittings, and cargo hooks) doesn't result in loss of control of the *rotorcraft* (3.1.1) or cause substantial damage to the airframe

3.9.11
hover
component of *mission-task-elements* (3.9.1) used to demonstrate the ability to transition from translating flight to a stabilized position over ground with precision and a reasonable amount of aggressiveness and to maintain precise position, heading, and altitude in the presence of a moderate wind from the most critical direction in the GVE, and with calm winds allowed in the DVE

3.9.12
landing
component of *mission-task-elements* (3.9.1) used to demonstrate the ability to precisely control the *rotorcraft* (3.1.1) position during the final descent to a precision touch-down point

3.9.13
slope landing
component of *mission-task-elements* (3.9.1) used to demonstrate the adequacy of any stability and control augmentation system changes that respond to partial or full landings and the ability to precisely coordinate control of the heave axis and lateral axis in contact with the ground

3.9.14
hovering turn
component of *mission-task-elements* (3.9.1) performed at hovering altitude in which the nose of the *helicopter* (3.1.2) is rotated either left or right while maintaining position over a reference point on the surface in order to check:

— for undesirable handling qualities in a moderately aggressive turning;

— ability to recover from a moderate rate hovering turn with reasonable precision;

— for undesirable *interaxis coupling* (3.9.5)