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Aerospace — Fluid systems — Vocabulary —

Part 4: General terms and definitions relating to control/actuation systems

Aéronautique et espace — Systèmes de fluides — Vocabulaire —

Partie 4: Termes et définitions généraux relatifs aux systèmes de commande/d'actionnement

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Foreword

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ISO 8625-4 was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 10, *Aerospace fluid systems and components*.

ISO 8625 consists of the following parts, under the general title *Aerospace — Fluid systems — Vocabulary*:

— *Part 1: General terms and definitions relating to pressure*

— *Part 2: General terms and definitions relating to flow*

— *Part 3: General terms and definitions relating to temperature*

— *Part 4: General terms and definitions relating to control/actuation systems*

Introduction

ISO 8625 contains only those terms which can be applied to general equipment and systems. Terms which are only used for specific applications and specific components are to be incorporated into the relevant product specifications and product standards.

Terms and definitions for components and systems which are associated with other systems (such as electromechanical actuation systems or electronic control units) are incorporated only on a very general basis, provided they have direct interfaces with fluid systems.

Aerospace — Fluid systems — Vocabulary —

Part 4: General terms and definitions relating to control/actuation systems

Scope

This part of ISO 8625 defines general terms relating to control/actuation systems in the field of aerospace fluid systems and components.

Terms and definitions

For the purposes of ISO 8625, terms have been given a two-element number: the first element refers to the number of the part of ISO 8625 in which the term is defined and the second element refers to the reference number of the term within that part.

EXAMPLE

4.3.38
velocity vs. force/torque characteristics
the term "velocity vs. force/torque characteristics" is defined in ISO 8625-4

Terms are presented according to the alphabetical order of terms in English.

4.1 Control system classification

4.1.1
adaptive control system
control system which improves system performance by changing system parameters in response to varying operational conditions

4.1.2
AFCS
automatic flight control systems
systems consisting of electrical, mechanical and hydraulic components that generate and transmit automatic control commands, which provide pilot assistance through automatic or semiautomatic flight path control or which automatically control airframe response to disturbances

NOTE 1 This classification includes automatic pilots, stick or wheel steering, autothrottles, structural mode control and similar mechanizations.

NOTE 2 AFCS functions include, but are not limited to, airspeed hold, automatic navigation, all weather landing, automatic terrain following, altitude hold, heading hold, altitude select, heading select, attitude hold (pitch and roll), lateral acceleration and sideslip limiting, automatic instrument, low approach mach hold, automatic carrier landing, automatic vectoring modes.

4.1.3
autobrake
automatic/electronic control of braking of a specific energy level

4.1.4
autoland
automatic/electronic control that takes the aircraft all the way to a full land

4.1.5
autothrottle
control means which sets a given position to maintain thrust for a given attitude/speed combination

4.1.6
bistable control system
control system in which the control output is fully on in either polarity

NOTE When the time is modulated by the input, the system is called pulse width modulated (PWM). The terms "ON-OFF control" and "bang-bang control" are sometimes used. These types of controls pertain to digital controls.

4.1.7
closed-loop control system
control system in which measurement of the output parameter is used to make system corrections so as to maintain a desired output based on input commands

4.1.8
CAS
control augmentation system
vehicle flight control system wherein the control system responds to the error between commanded vehicle motion and the actual vehicle motion as well as to surface position command inputs

4.1.9
control and stability augmentation system
combination of **CAS** (4.1.8) and **SAS** (4.1.20)

4.1.10
control authority
total amount of control surface or force effector deflection available to a flight control system

NOTE The prefixes "pilot", "CAS" or "SAS" are often used to define that part of the total available to the pilot, the CAS or the SAS, respectively.

4.1.11
control system
system in which deliberate guidance or manipulation is used to achieve a prescribed value of a variable

NOTE A control system has at least one input and one output.

4.1.12
digital control system
control system which uses digital signals and wherein the control information is digital

4.1.13
flight control systems
systems that enable the controlled flight of aircraft, helicopters and missiles

NOTE "Manual flight control systems" transmit pilot commands through mechanical components, though they often incorporate electrical components to augment the pilot commands. The term is also sometimes used for those systems which transmit pilot commands to the surfaces mechanically, without power or force assistance.

4.1.14
fly by wire (FBW) system
control by wire (CBW) system
control system wherein control information and signals are transmitted completely by electrical means

4.1.15
fly by light (FBL) system
control by light (CBL) system
control system wherein control information is transmitted by light through a fibre optic cable

NOTE A true FBL system does not have FBW or mechanical backup, nor FBW or mechanical override.

4.1.16
hydraulic boost
use of hydraulic power actuation to reduce the pilot effort needed for control of a vehicle wherein the actuator output force or torque is in direct proportion to the manual, mechanically applied, input force or torque

4.1.17
integral control system
control system, which uses an integrator in the control loop elements to provide an output response to the error signal, and for which the control effort is proportional to the integral of the error

4.1.18
open-loop control
control system in which an output is produced in direct response to a command, without feedback from the output being used to affect the system response

4.1.19
proportional control system
control system which uses proportional control elements in its forward or feedback control paths, or both, to provide an output in response to the error signal

4.1.20
SAS
stability augmentation system
portion of a flight control system that improves the handling characteristics by modifying the aerodynamic response of the vehicle

NOTE The SAS generally has limited authority. SAS signals are normally introduced by a series servo, the operation of which does not have an impact on the pilot's command signal.

4.1.21
tristable control system
control system in which the power to control the load is fully on in one polarity, off, or fully on in the other polarity (tristable)

NOTE When the time is modulated by the input, the system is called pulse width modulated (PWM). The terms “ON-OFF control” and “bang-bang control” are sometimes used. These types of controls pertain to digital controls.

4.2 Control system technology (control engineering)

4.2.1
backlash
uncontrolled load motion due to clearance in actuation elements, including the load attach point, usually expressed in terms of absolute load motion

4.2.2
bandwidth
frequency range over which the actuation system has acceptable dynamic response

NOTE This spectrum extends from a base frequency up to a specified frequency, which is usually the frequency where the open-loop amplitude ratio has unity gain (0 dB) in other than single order systems. For a first order system, this is the frequency where the closed-loop response is down 3 dB and the phase lag is 45° [see also **decibel** (4.2.6)].

4.2.3
closed-loop frequency response
frequency response between command input and control system output with the feedback signal summed algebraically with command

NOTE Actuation system response for a closed-loop system is usually specified as closed-loop frequency response.

4.2.4
command
input which represents the desired output of the control system

4.2.5
control passband
frequency range over which the control responds without attenuation

4.2.6
decibel
dB
unit of measure used to express amplitude ratio of output to control input

NOTE Decibels = 20 $\log_{10}$ (amplitude out/amplitude in).

4.2.7
dynamic impedance
impedance, a complex quantity, associated with the output deflections of an active, closed-loop actuation system caused by externally applied dynamic forces, usually sinusoidal, over a specific frequency range

NOTE Dynamic impedance at the surface includes the effects of the surface attachment spring, its load mass and its viscous friction. The impedance at the actuator will not include these factors.

4.2.8
error signal
algebraic difference between the command input and the output feedback

4.2.9
feedback element
component in a closed-loop system that provides the feedback signal of the output quantity, or a function of the output that can be compared with the reference input

4.2.10
forward loop control elements
elements situated between the error signal and the controlled variable

4.2.11
frequency response
complex ratio of the actuation system output to the command input while the input is cycled sinusoidal at a constant amplitude and the frequency is varied

NOTE Frequency response is usually presented as a log frequency plot of normalized amplitude ratio, expressed in dB, and input to output phase angle degrees versus frequency.

4.2.12
gain crossover
point of the plot of the open-loop transfer function at which the magnitude is unity (LmG (jω) = 0 dB)

NOTE The frequency at gain crossover is called the phase margin frequency, $\omega_{\varnothing}$.

4.2.13
gain margin
measure of system stability defined as the gain required to raise the open-loop amplitude ratio to 0 dB (unit gain) at the frequency corresponding to 180° of phase lag

4.2.14
hysteresis
difference in actuation system output for the same input command level during a complete cycle of input command when cycled throughout the full range of travel

NOTE It is necessary that the cycling rate be significantly below the control bandpass so that velocity error signals are not included in this parameter.

4.2.15
input
independent variable supplied to the control system

4.2.16
linearity
degree to which the normal output curve conforms to a straight line under specified load conditions, usually expressed as a percentage of full range, or sometimes of rated output, which is typically half full range

4.2.17
load natural frequency
undamped resonant frequency of the load mass, coupled with the frequency-independent dynamic stiffness

4.2.18
loop
signal path in a closed-loop control system beginning with the error signal after a summing point and ending with the resultant feedback signal returning to the same summing point

4.2.19
normal output curve
locus of the mid-points of a complete input/output curve

NOTE This locus is the zero hysteresis output curve.

4.2.20
normal output gain
slope of the normal output curve in units of output/input

4.2.21
open-loop frequency response
frequency response between command input and control system output with no outer loop feedback loop closure

4.2.22
output
controlled variable resulting from activity of the control system

4.2.23
input/output curve
graphical representation of actuation system output versus command input

NOTE This is usually a continuous plot throughout a complete cycle between plus and minus rated commands. The cycling rate must be significantly below control bandpass, so that velocity error signals are not included in this parameter.

4.2.24
overshoot
increment by which the output exceeds the desired output value when responding to a step command, usually expressed as a percentage of the output [see also **step response** (4.2.30)]

4.2.25
phase crossover
point of the plot of the open-loop transfer function at which the phase angle is −180°

NOTE The frequency at which phase crossover occurs is called the gain margin frequency, W_C.

4.2.26
phase margin
measure of system stability, defined as the phase lag to be added to the open-loop frequency response in order to achieve 180° of phase lag at the frequency corresponding to 0 dB amplitude ratio

4.2.27
resolution
accuracy with which the actuation system output can be positioned, usually measured as the smallest increment of command that can cause reversal of output motion

NOTE It is the smallest increment of the output value. Output accuracy is usually expressed in absolute terms, i.e. a position resolution of 0,5°.

4.2.28
servoactuator stiffness
stiffness of a hydraulic servoactuator closed-loop, which is frequency dependent as indicated by the notation:

$$K_{act}(j\omega)$$

4.2.29
signal ramp
function of input signal versus time, which is normally a linear function

4.2.30
step response
time response of the actuation system output following a step command input

NOTE Step response is usually specified as the time required to reach a particular percentage of the final output, together with limits on the percentage overshoot.

4.2.31
stiffness
performance characteristic of an actuator that expresses the degree of resistance its output member offers against the constant or varying loads encountered, either while maintaining or changing its positional output

4.2.31.1
actuation stiffness
stiffness of an actuation system, which is a measure of its ability to minimize the motion of the load induced by an external force or torque at the output

NOTE Typically defined as the force required to produce unit motion of the load. This is evaluated by applying force or torque to the load (e.g. the control surface, rocket nozzle, etc.).

4.2.31.2
actuator stiffness
stiffness of an actuator, which is a measure of its ability to minimize the motion of the actuator output induced by an external force or torque at the output

NOTE Typically defined as the force required to produce unit motion of the actuator output. This is evaluated by applying force or torque at the actuator output shaft.

4.2.31.3
back-up stiffness
combined stiffness of all of those elements of the structural load path that allow motion of the actuator structural attach point with respect to structural ground

NOTE This does not include any compliance contribution from the actuator or from the load path that connects the actuator output to the driven load.

4.2.31.4
drive stiffness
net stiffness of an actuation system when installed in its host structural environment, referenced to the structural ground point

NOTE Drive stiffness is represented by the formula:

$$\frac{1}{K_{\text{eff}}(\text{j}\,\omega)} = \frac{1}{K_{\text{S1}}} + \frac{1}{K_{\text{act}}(\text{j}\,\omega)} + \frac{1}{K_{\text{S2}}} \tag{1}$$

where

$K_{\text{eff}}(\text{j}\omega)$ is the drive stiffness;

K_{S1} is the spring rate of the supporting structure from actuator to hinge line;

K_{act} is the actuator spring rate;

K_{S2} is the control surface structure spring rate;

ω is the oscillation frequency of the applied force.

4.2.31.5
dynamic stiffness
stiffness of an actuator, usually closed-loop, as a function of frequency, when loaded by a sinusoidal forcing function

NOTE It is necessary that the dynamic stiffness of an actuation system driving an inertial load consider the entire **drive stiffness** (4.2.31.4), rather than only the **actuator stiffness** (4.2.31.2) and also the impedance of the driven mass.

4.2.31.6
fluid stiffness
stiffness due to change in fluid volume resulting from the application of an external load

EXAMPLE Actuator piston centred:

$$k_0 = \frac{4 \times \beta \times A^2}{V_\text{t}} \tag{2}$$

where

k_0 is the fluid stiffness;

β is the bulk modulus;

A is the piston area;

V_t is the total fluid volume $V_1 + V_2$;

V_1, V_2 is the volume in one actuator chamber with piston centred.

4.2.31.7
infinite frequency stiffness
dynamic stiffness at infinite frequency

4.2.31.8
mechanical stiffness
net stiffness of all mechanical load-carrying elements of an actuator

NOTE 1 Mechanical stiffness is defined by

$$\frac{1}{k_m} = \frac{1}{k_b} + \frac{1}{k_r} + \frac{1}{k_c} + \frac{1}{k_p} + \frac{1}{k_t} + \cdots \quad (3)$$

where

k_m is the mechanical stiffness.

The stiffness elements k_b, k_r, k_c, k_p and k_t are attributable to:

k_b rod-end and tail stock bearings;

k_r piston rod;

k_c cylinder barrel;

k_p piston head;

k_t tail stock.

NOTE 2 k_c, k_p and part of k_r are within the closed actuator position loop and will therefore not contribute to the static stiffness of the actuator but will appear in the infinite frequency stiffness since the position loop is ineffective at high frequencies. Conversely, the remaining elements are outside the position loop and will contribute to the actuator mechanical stiffness at all frequencies.

4.2.31.9
overall actuation stiffness
stiffness determined by the actuator static stiffness in parallel with the load-centring stiffness

4.2.31.10
servoactuator stiffness
stiffness of an actuator including stiffness elements of the servoloop

NOTE Servoactuator stiffness is defined by

$$\frac{1}{k_{act}} = \frac{1}{k_{SL}} + \frac{1}{k_{ext}} \quad (4)$$

where

k_{SL} is the actuator servoloop stiffness;

k_{ext} is the combined mechanical stiffness external to the servoloop;

k_{act} is the actuator stiffness.

4.2.31.11
static stiffness
low-frequency stiffness
the closed-loop servo actuation system stiffness at or near zero oscillation frequency

4.2.31.12
stiffness to ground
combined stiffness of all spring rates which determines the spatial reference of the load mass

NOTE This stiffness, in conjunction with the load inertia, determines the load natural frequency.

4.3 Control system performance (servomechanism)

4.3.1
actuator
component of an actuation system which does work or dissipates energy to control a load

NOTE Actuator output is achieved by conversion of energy from the power system or load into mechanical work, torque, or force. The different types of actuators are mentioned and defined in the relevant component related documents, e.g. component specifications, design standards.

4.3.2
aiding load
force or torque on the actuator provided by load restoration or inertia, or both, which acts in the same direction as the desired direction of load motion

NOTE See also **opposing load** (4.3.24).

4.3.3
actuator bias load
steady-state load that is unidirectional and constant over full load travel

4.3.4
actuator coulomb friction load
external constant friction load opposing motion, dependent only upon the magnitude of the load and the condition of the sliding surfaces

4.3.5
actuator duty cycle
description of the load throughout the total mission time with sufficient detail to determine rate requirements, frequency of occurrence and dynamic load characteristics

NOTE A complete duty cycle description defines the actuation energy required for the total mission.

4.3.6
actuator rated load
specified steady-state load applied to the actuator for determining rated velocity

NOTE Rated load is usually an opposing load.

4.3.7
actuator spring load
external load which varies proportionally with load position

NOTE This load can be caused by aerodynamic forces on a movable surface, or by thrust deflection reaction forces on a movable nozzle element.

4.3.8
actuator stall load
minimum load under which the servoactuator ceases to move when the power source is at its limit and the command signal is increased, i.e. the load which the servoactuator cannot overpower

4.3.9
actuation system
means of power utilization for controlling a specific output variable

NOTE Actuation systems include a power source, power converter, controller, actuator and feedback element (if used).

4.3.10
actuator viscous friction load
friction load opposing motion and proportional to load velocity

4.3.11
clutch coupling drive
motion transmission which allows interruption of the load path for control purposes

4.3.12
controller
component of the actuation system which controls the power to the actuator as a function of the command or error signal

4.3.13
direct coupling drive
motion transmission with a continuous load path

4.3.14
EHA
electrohydrostatic actuator
actuation package wherein its hydraulic actuator is coupled directly to the output of a bidirectional fixed displacement pump that in turn is driven by an electric motor

NOTE The actuator output motion is proportional to motor-pump motion. The main elements of an EHA package usually include a hydraulic actuator, bidirectional fixed displacement pump, electric motor, reservoir, motor controller and optional logic valves.

4.3.15
force/torque summing drive
multichannel summing arrangement which sums the torque or force outputs of redundant elements into a single output

4.3.16
inertia load
load opposing any change in the state of motion, proportional to load acceleration and inertia

4.3.17
IAP
integrated actuator package
actuation package wherein its hydraulic actuator is coupled directly to the output of a constant speed variable displacement over-centre pump, which in turn is driven by an electric motor

NOTE The actuator output velocity is proportional to pump displacement. The main elements of an IAP package usually include a hydraulic actuator, variable displacement over-centre pump, constant speed electric motor, reservoir and optional logic valves. An additional boost pump is often included to prevent main pump cavitation and to power the main pump's displacement controller.

