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Aerospace — Electrohydrostatic actuator (EHA) — Characteristics to be defined in procurement specifications

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National foreword

This British Standard is the UK implementation of ISO 22072:2011. It supersedes BS ISO 22072:2005 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee ACE/69, Aerospace hydraulic systems, fluids and components.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Aerospace — Electrohydrostatic actuator (EHA) — Characteristics to be defined in procurement specifications

Aéronautique et espace — Actionneurs électrohydrostatiques (EHA) — Caractéristiques à définir dans les spécifications d'approvisionnement

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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.

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The main task of technical committees is to prepare International Standards. 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.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 22072 was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 10, *Aerospace fluid systems and components*.

This second edition cancels and replaces the first edition (ISO 22072:2005), which has been technically revised. This second edition adds requirements for electronic module hardware (4.3.5), operation under failure conditions (4.4.5), electrical power consumption and regeneration (4.5) and fatigue wear life (4.7.2).

Introduction

Electrohydrostatic actuators (EHAs) are integrated, electrically powered, hydraulic actuators that are used to power aircraft control surfaces or other moving parts.

This International Standard provides requirements that should be included in a Procurement Specification for this type of actuator.

Aerospace — Electrohydrostatic actuator (EHA) — Characteristics to be defined in procurement specifications

1 Scope

This International Standard defines the general characteristics, requirements and design data to be included in the procurement technical specification of an electrohydrostatic actuator (EHA) to be used to power aircraft control surfaces or other moving parts of an aerospace vehicle.

This type of actuator is an alternative to the hydraulically powered servo-control actuators that are currently used. It is intended that this International Standard cover the unique requirements of EHAs.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 7137, *Aircraft — Environmental conditions and test procedures for airborne equipment*

DO-178B, *Software Considerations in Airborne Systems and Equipment Certification*[1)]

DO-254, *Design Assurance Guidance for Airborne Electronic Hardware*[1)]

SAE ARP1383B, *Impulse Testing of Aerospace Hydraulic Actuators, Valves, Pressure Containers, and Similar Fluid System Components*[2)]

3 Terms and definitions

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

3.1
electrohydrostatic actuator
EHA
an electrically powered actuator that includes one or several hydraulic rams

NOTE 1 The chambers of each ram are connected to an integrated hydraulic fluid reservoir and to a bidirectional, fixed-displacement pump driven by a variable-shaft-speed, bidirectional electric motor controlled by an electronic module including power electronics, mounted on the actuator or remotely, and considered a part of the actuator.

NOTE 2 The motor/pump/power electronics assembly may be incorporated into a standard Electrohydrostatic Module (EHM).

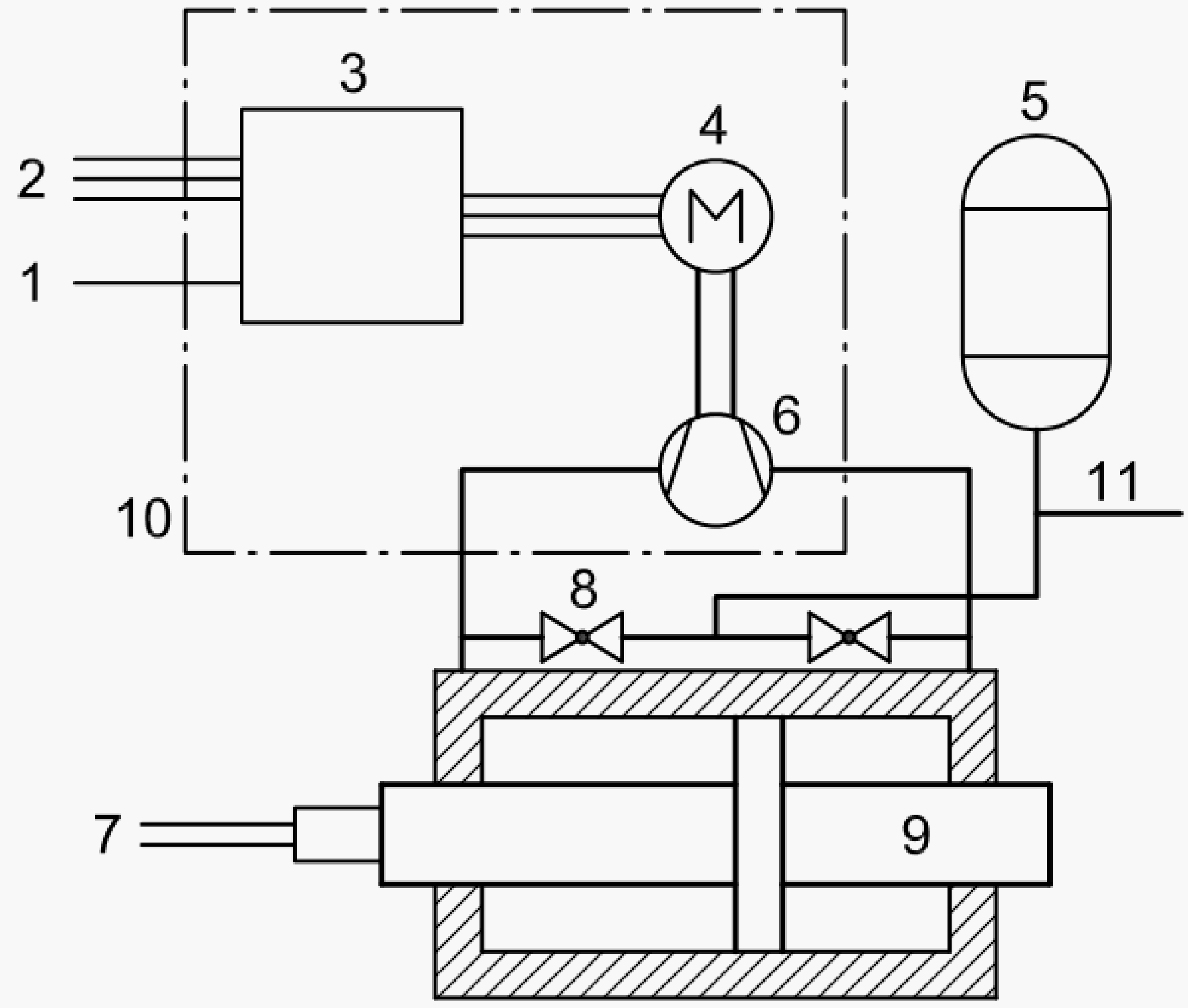
1) RTCA – Radio Technical Commission for Aeronautics, www.rtca.org.

2) SAE – Society of Automobile Engineers, www.sae.org.

NOTE 3 A manifold, in which components necessary for additional functions can be installed, interconnects the mechanical elements; see Figure 1. The additional functions may include, for example, allowing the operation of other actuators installed in parallel, or ensuring the damping of movement of the load in case of loss of all electric power.

NOTE 4 This assembly is part of the position control loop of the surface, or of any other load, in which the error signal, difference between the commanded and achieved positions determines the command of the speed and direction of rotation of the motor. Other components of the position servo-loop, e.g. position transducer, control electronics, generating the error signal and control laws, do not necessarily form part of this assembly.

NOTE 5 The electronic module function may be limited to Motor Drive Electronics (MDE), higher-level functions such as closing the position loop, control laws, failure detection and isolation, and built-in-test being implemented in a central computer, or these functions can be included as an Electronics Control Unit (ECU).



Key

1 command signal
2 power supply
3 electronic module
4 electric motor
5 reservoir
6 pump
7 position transducer signal
8 anti-cavitation check valve (two places)
9 piston
10 EHM
11 filling port

Figure 1 — Typical arrangement of an electrohydrostatic actuator

3.2
digital signal processor
DSP
integrated circuit designed for processing signals by digital means as opposed to analogue means

3.3
field-programmable gate array
FPGA
integrated circuit designed to be configured by the designer or user after manufacturing

4 Requirements

4.1 General

The requirements defined in 4.2 to 4.13 shall be met under all rated operating conditions and during the service life specified.

4.2 Brief description of the system

The EHA is one component of a system. The various configurations or reconfigurations typical of this system involve specific modes of EHA operation which shall be described. Normal and failure modes of operation for the EHA shall be defined.

4.3 Description and interfaces

4.3.1 General description

The unit shall be described in terms of functions and the associated terminology defined.

The following are examples:

- control/electrical/mechanical/structural redundancy;
- local or remote fluid level indication/monitoring;
- filling, either from a ground support equipment or a central hydraulic system;
- draining;
- bleeding;
- internal fluid filtering;
- anti-back-driving device;
- local dissipation of generated energy;
- force and/or pressure and/or speed limitation;
- stops;
- temperature monitoring;
- heating of stand-by unit; etc.

4.3.2 Mechanical interface

The specification, or a separate interface control document, shall define:

- allocated space envelope;
- dimensions and tolerances of the mechanical connections or the dimensional standards if connections are achieved through standardized components;
- line replaceable units;
- access once installed on aircraft;
- interfaces with specific items (such as hoisting devices or “jack catchers”) intended to hold the unit in place in the event of attachment rupture or disconnection, to avoid secondary damage to surrounding structures or equipment, etc., as required.

4.3.3 Electrical interface

The specification, or a separate interface control document, shall include:

— wiring schematics defining the electrical connections with power supply, control and monitoring systems, standards, sizes and pin allocation of interface connectors;

— any particular requirements or limitation on use of connectors for the line replaceable units;

— segregation rules to comply with, including signal separation requirements;

— descriptions of signals exchanged, definition of input and output impedances;

— power interruption capability and definition of the strategy for longer interruptions (see 5.3);

— bonding interface;

— shielding requirements;

— specific insulation requirements associated with the use of high voltage d.c.

4.3.4 Hydraulic interface

The hydraulic interface requirements shall include definition and location of possible filling, bleeding, filtering and draining features.

4.3.5 Electronic module hardware, software/firmware

Various control and monitoring functions, such as listed below, can be implemented locally in the embedded electronic module, which is primarily intended to host the motor drive electronics, or shared with central computers:

— loop closure;

— monitoring and redundancy management;

— status information;

— built-in test;

— allowable type of processor such as DSP or FPGA may be specified; etc.

The level of criticality and of the associated development, verification and validation methods, configuration control, applicable to the software and firmware shall be specified with reference to DO-178B and DO-254.

Memory capacity extension and processing power shall be specified.

Implementation of monitoring functions may require physical segregation, independent hardware, possible hardware and software dissimilarity, depending on criticality.

4.4 Performance

4.4.1 General

The EHA should meet the performance requirements when operating in conjunction with the other servo-loop components.

4.4.2 Mechanical performance

The definition of the requirements for output force or mechanical power shall take into account the thermal behaviour. These mechanical requirements shall therefore be associated with their duration and environmental conditions. They shall take into account any included force, pressure or speed limitation functions. Thus the following shall be specified.

a) Maximum operating output force: the maximum driving force to be generated by the unit at very low speed (to be defined), for a short time duration (to be defined), under specified supply and environmental conditions, and the associated tolerances.

b) Maximum continuous output force: the maximum holding force, with no movement, or the maximum driving force, at very low speed (to be defined), to be generated under given supply and environmental conditions with no time limitation, with and without its possible no-back device engaged, and the associated tolerances.

c) "Worst case" scenarios: operational sequences, or series of sequences, described as functions of time in terms of position, force, environmental conditions, identified as sizing cases in terms of instantaneous power absorbed or rejected, or in terms of heat generated. Force fighting shall be considered, depending on system configuration.

d) Maximum rate and associated loading conditions, or expressed as the time necessary to reach a given position under a specified load. The rate versus load characteristic shall be identified.

e) Run-up time: time from activation of stand-by actuator to being able to achieve maximum rate with a maximum rate demand.

Dynamic performance as specified below may also be a sizing consideration:

— working stroke, stop-to-stop stroke;

— possible acceptable temporary degradation of performance at start-up, following cold soak in particular;

— possible acoustic noise requirements;

— possible allowed performance degradation under extreme conditions.

4.4.3 Servo-loop static performance

The following characteristics, with and without the possible anti-back-driving device, shall be specified either as the complete servo-loop requirement or as the part allocated to the actuator, taking into account data under 5.6:

— overall accuracy;

— hysteresis;

— resolution;

— stiffness;

— freeplay;

— force fighting, depending on system configuration;

— possible allowed performance degradation under extreme conditions.

4.4.4 Servo-loop dynamic performance and stability

The following shall be specified either as the complete servo-loop requirement or as the part allocated to the actuator, taking into account data under 5.6:

- maximum no-load rate, including, as applicable (in terms of percentage), command amplitude and frequency;
- maximum no-load acceleration due to motor voltage/current saturation, including, as applicable (in terms of percentage), command amplitude and frequency;
- maximum regenerative power;
- bandwidth of the position servo-loop, expressed in terms of amplitude ratio and phase lag in the frequency range, for defined amplitudes and loads;
- maximum acceptable overshoot to a step input of specified amplitude;
- minimum acceptable stability margins of the position servo-loop and any inner control loops (ex: motor speed);
- acceptable speed oscillation, characterized by frequency and amplitude (motor and pump may generate torque ripple);
- response time of the possible anti-back-driving device;
- acceptable limit cycle (an anti-back-driving device may generate a limit cycle);
- dynamic stiffness;
- force fighting, depending on system configuration;
- possible allowed performance degradation under extreme conditions.

4.4.5 Operation under failure conditions

Desired behaviour in the event of supply/control computer/electronic module or other failures shall be specified, including transient performance.

Possible specific EHA failure modes shall be addressed (e.g. motor/pump possible over speed when back-driven by the load).

4.5 Electrical power consumption and regeneration

4.5.1 Consumption

Power factor and in-rush current, steady-state power consumption with no movement, as a function of the applied load, and peak consumption in the course of typical manoeuvres, under specified supply and ambient conditions, shall be specified.

4.5.2 Regenerative energy

Under aiding load operation or deceleration, the motor generates electrical energy. The way and the conditions under which this energy is to be handled, either dissipated locally or put back on the aircraft power bus, shall be specified.

4.6 Hydraulic consumption

Allowable fluid loss, allowable refill interval, and life of fluid shall be specified.

4.7 Strength and life

4.7.1 Static strength

Static strength is defined by the following.

a) *Limit load* (without permanent deformation or leakage): maximum driving or resisting force capability of the unit, with account taken of any force limitation function possibly incorporated. In the case where an anti-back-driving device is included, the maximum holding force may define this limit load.

b) *Ultimate load* (without rupture): ×1,5 limit load.

c) *Proof pressure* (without permanent deformation or leakage): ×1,5 maximum permanent pressure associated with the limit load or ×1,5 maximum operating pressure. For lines only submitted to the fluid compensator pressure: ×1,5 maximum fluid compensator pressure.

d) *Ultimate pressure* (without rupture): ×2 maximum permanent pressure associated with the limit load or ×2 maximum operating pressure. For lines only submitted to the fluid compensator pressure: ×2 maximum fluid compensator pressure.

NOTE The above factors are recommended values. Other sizing cases, not specific to EHA and depending on the system configuration, may apply.

e) If the actuator is connected to a hydraulic system, in order to avoid the need to service for example, the usual hydraulic system sizing conditions shall apply to all parts exposed to the system pressures.

f) The EHA shall be able to withstand any bottoming loads corresponding to the design conditions of the control system.

4.7.2 Fatigue and wear life

The fatigue life under external loads, acceleration, and pressure transients possibly generated by the operation of the unit is associated with the absence of crack initiation. Generally the fatigue life of the actuator is equivalent to the structural life of the vehicle. Appropriate scatter factors shall be used.

If the actuator is connected to a hydraulic system, the usual hydraulic system pressure impulse requirements, SAE ARP1383B or specific requirements shall apply to all parts exposed to the system pressures.

The wear life under external loads, strokes, velocities, acceleration, and combinations thereof, is associated with the absence of component wear resulting in unacceptable degradation of performance. Generally, the wear life of the actuator is equivalent to the structural life of the vehicle. Appropriate scatter factors shall be used.

All components do not necessarily have the same life objective.

4.8 Protection against fire risk

Special precautions against fire risk shall be specified, covering normal operation and failure conditions:

— protection and monitoring functions;

— physical separation;

— precautions against short circuits;

— precautions against electric arcs;

— maximum acceptable temperatures at specific locations (skin, fluid, power electronics, etc.);

— fluid contact with hot parts;

— dispersal of possible leakage;

— explosion-proof provisions.

4.9 Reliability and safety

The criticality level shall be defined.

Reliability shall be specified according to the application (mean time between failures).

Safety shall be expressed in terms of probability of loss of function, loss of control, runaway, etc.

4.10 Bonding

Maximum resistance between any point of the EHA and the bonding connection shall be specified.

4.11 Lightning, electromagnetic compatibility

In accordance with ISO 7137, or applicable specifications, requirements and/or levels shall be specified.

Direct lightning strike effects shall be specified.

4.12 Maintainability and servicing

Maintainability requirements shall include, where applicable,

— markings;

— handling devices for heavy equipment;

— checking the fluid level;

— fluid contamination control;

— fluid level settings, bleeding, drainage, and renewing, on aircraft or in the workshop;

— definition of line replaceable units (LRUs);

— tests based on the observation of such parameters as speed or current;

— built-in fault detection and isolation;

— probable maintenance errors to be taken into account as design criteria;

— appropriate devices/warnings to cover safety hazards possibly generated by fluid compensators, capacitors, high d.c. currents, etc.;

— standardization of hardware, fittings and common tools.

4.13 Thermal requirements

Maximum heat rejection, maximal fluid and skin temperature shall be specified.

5 Installation and operating conditions

5.1 General

Data on the general environment and intended operating conditions for which the unit shall be designed are specified in 5.2 to 5.8.

5.2 Mechanical data

The mechanical data shall include the following:

- geometry and output load kinematics;
- inertia of the load;
- nature and characteristics of the load – aiding and/or resisting forces, constant or viscous frictions;
- load attachment stiffness;
- fixed structure attachment stiffness.

5.3 Electrical supply data

The electrical supply data shall include the following:

- characteristics of the power supply (see, for example, ISO 7137, EN 2282, MIL-STD-704), and especially generator impedance (power interruption definition is of prime importance);
- acceptable harmonic distortion;
- possibility of rejecting power to the network and under what form;
- wiring characteristics;
- circuit-breaker characteristics.

5.4 Thermal data

The thermal data shall include the following:

- surrounding structural materials' thermal characteristics;
- possible heat sink thermal characteristics;
- velocity/mass flow of the circulating air;
- closed volume;
- external heat source characteristics.

5.5 Hydraulic data

The indicated hydraulic data need to be specified only if the user or anyone other than the supplier intends to service the EHA's hydraulic fluid. It shall include the following:

— type of fluid;

— maximum level of contamination of the fluid used for servicing;

— pressure characteristics of possible filling devices.

5.6 Control and monitoring data

Control and monitoring data shall include all pertinent information on the servo-loop and the monitoring functions.

5.7 Environmental data

Except when otherwise specified, the environment and operating conditions to which the EHA is exposed shall be in conformity with ISO 7137.

If power electronics are not installed at the same location as the rest of the actuator, different conditions apply.

5.8 Duty cycle data

The duty cycle is the defined variation of a set of relevant operating conditions, position, load, throughout the mission, expected over the life of the unit, to be used for the fatigue, wear, thermal sizing and the validation of the product.

For hydraulic servo-controls, the following parameters are usually used: the variation of the mode of operation, the position of the servo-control and the forces applied during the course of an "average" mission, the possibly superimposed control signal noise. The movements are normally random but with a strong sinusoidal content and are customarily reduced to a description of a mixture of sinusoidal varying amplitudes of position and load. These data are used for the design or validation of the structural and wear life, and are presented in a form "rationalized" for this purpose.

The duty cycle definition evolves during the course of the programme: a requirement for design is initially established by analysis, then adjusted for validation, for example on the basis of flight tests results. Validation testing of hydraulic actuators is customarily accelerated by accumulating the total specified cycles at frequencies far higher than seen in flight.

However, because they are electrically powered, EHAs need supplementary duty cycle data for the thermal design and validation. These include:

— in addition to the definition of the "average" mission, identification of operating phases or complete missions that may be thermal sizing cases (aircraft failure cases, exceptional level of turbulence, training flights with repetition of manoeuvres at critical temperatures, operation during the course of maintenance activities, possible maintenance errors, such as a permanent command applied while on stops, etc.);

— the duration of application of forces and actuator displacement;

— the possible absence of rest period between two successive flights;

— the ambient temperature and air pressure.

In addition, the pump endurance testing shall replicate actual accelerations from the aircraft flight profiles.

Any definition of the duty cycle to sinusoidal equivalent motion and force variation:

— shall pay careful attention to the distribution of activity over the duration of the mission;

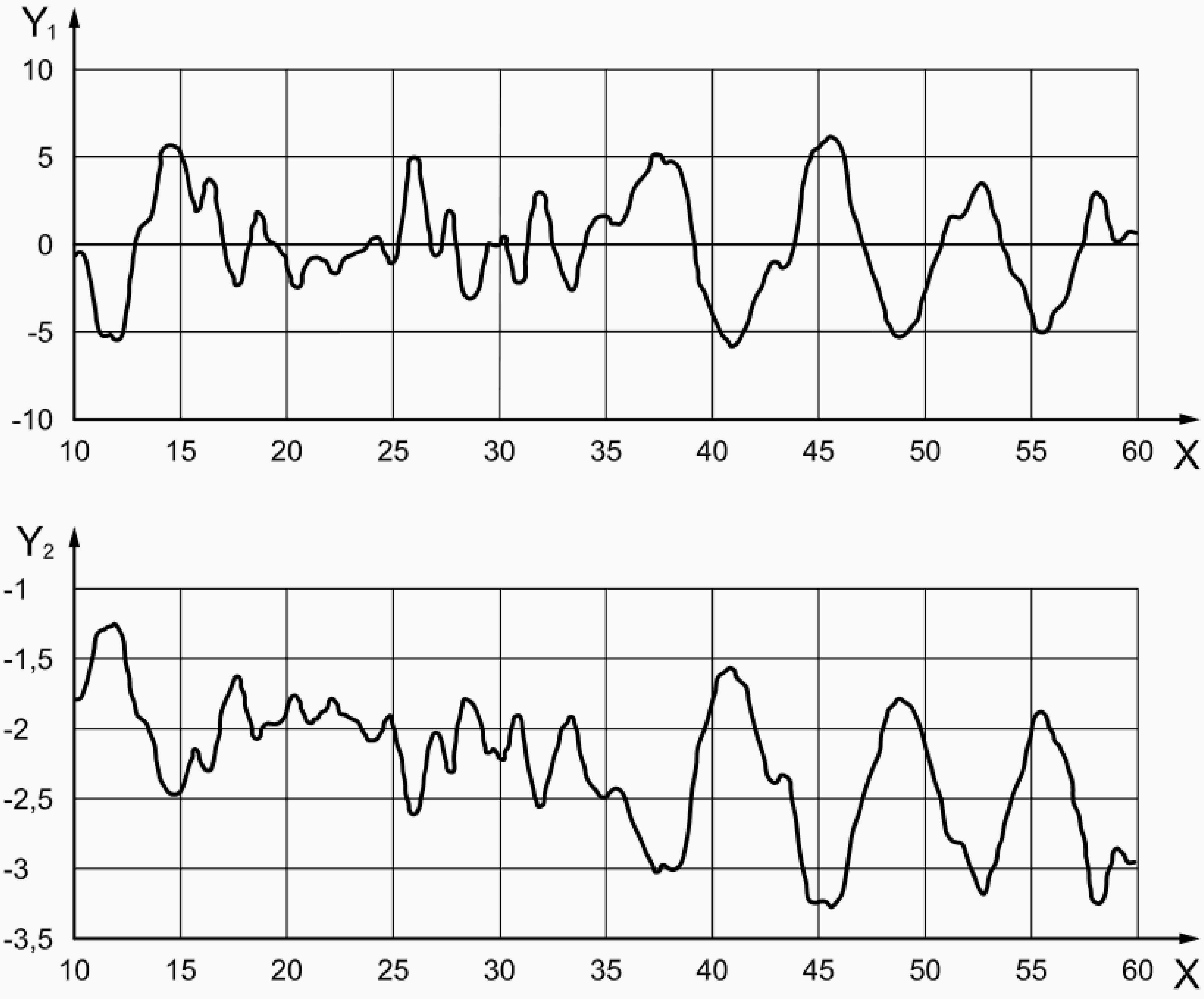
— shall not use methods of regrouping or counting movements based only on fatigue, wear considerations or eliminating time-related information.

The most complete definition is determined by providing, for each operational phase:

— the duration of the phase;

— representative samples of the changes in the load position and the applied force/hinge moment. These are as a function of time associated with ambient air temperature and pressure information.

Figure 2 provides an example of control surface parameters.



Key

X time (s)

Y_1 surface deflection (degrees)

Y_2 hinge moment (mN)

NOTE Overspecifying the average duty cycle will reduce predicted reliability due to resulting increased temperatures.

Figure 2 — Surface deflection and hinge moment plotted against time

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[1] EN 2282, *Aerospace series — Characteristics of aircraft electrical supplies*

[2] MIL-STD-704, *Aircraft Electric Power Characteristics*

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