**Hazards of Excessive Pilot Flight Control Forces**

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This technical paper provides a historical summary of the chronological development of the flight control force regulations for airplanes and rotorcraft, reviews relevant aircraft mishaps, and presents a way ahead for proactively mitigating the hazard of excessive pilot flight control forces by providing valid flight control force-application strength data to ensure new aircraft designs account for the current pilot population demographic and flight control configurations.

**The Hazard**

Accident, incident, and anomalous event reports from the National Transportation Safety Board (NTSB) and the Aviation Safety Reporting System[[1]](#endnote-1) (ASRS) databases highlight the safety implications of continued reliance on the current regulations for pilot flight control forces that have been deemed by mishap pilots and investigators alike as requiring excessive strength, even though they may be compliant with the regulatory requirements.

*“The pilot reported, however, that even with he and the passenger exerting what the pilot described as*

*“maximum yoke back pressure,” the airplane’s negative, nose-down pitch attitude increased,*

*airspeed approached the maximum operating speed (for operation at less than 30,000 feet) of*

*263 knots, and rate of descent increased to approximately 2,000 feet per minute. The pilot also*

*stated that,* ***because of the severe control forces required, he could not safely remove either hand***

***from the control yoke for more than several seconds at a time to manipulate other flight deck controls****”.* (NTSB SEA03FA147)

*“In a nearly full nose up trim position,* ***I was barely able to exert enough force (I am a 200 lb male) on the yoke to stop the pitch up much less able to reduce it.*** *Not recognizing what was causing the problem or less physical* ***strength*** *would most definitely resulted in a departure stall.”*(ASRS 715548)

*“The autopilot was disconnected and when attempting to move the ailerons* ***it took both hands and excessive force to move the ailerons****. The reporter said the aileron problem was caused by the autopilot aileron servo that did not disconnect when the autopilot was switched off and was being back driven by manual inputs*.” (ASRS 417844)

*“As the pilot approached the survey location, the loss of hydraulic pressure most likely resulted* ***in very-high collective control forces*** *and pilot-induced oscillations."…high altitude operations could be compromised due to the high collective control force encountered without hydraulics assist, thereby restricting control travel.”* (NTSB CEN13FA415)

**The Regulations**

The maximum force requirements for manipulation of flight controls in transport category Part 25 airplanes are quantitatively specified in the Federal Aviation Regulations (FAR) under 14CFR §25.143(d) and European Aviation Safety Agency (EASA) regulations under Certification Specification (C.S.) 25.143(d) [Table 1]. The control force values were originally derived from data for 5th to 95th percentile males applying for U.S. military service in the 1950’s as published in Mil-Std-1472, Mil-Hdbk-759, Mil-F-8785, and DoD Hdbk-743, thus are not representative of the current civilian pilot population. These control force requirements, as originally adopted and published as Civil Aviation Regulations (CAR) §4b.130 in the 1950’s and subsequently converted to Federal Aviation Regulations under 14CFR §25.143 in the 1960’s, have not changed in over a half of a century other than two adjustments, even though the civilian population demographic has evolved considerably. In 1978, the yaw (rudder) maximum control force under 14CFR §25.143(c) Amendment 25-42[[2]](#endnote-2) was changed from 180 lbs to 150 lbs (667 N). based on flight test experience that had shown that 180 pounds may make control difficult for some pilots under some flight conditions. Seventeen years later the roll maximum control force under 14 CFR §25.143(c) Amendment 25-84[[3]](#endnote-3) was changed from 60 lbs to 50 lbs (222 N), and pitch and roll limits of 50 lbs and 25 lbs respectively were added to distinguish between long term and short application with only one hand available for control. Interspersed throughout the regulations is the requirement to not require exceptional pilot strength to perform a wide variety of ground and flight maneuvers. However, the term “exceptional strength” is not defined, although some of the guidance in FAA Advisory Circulars (AC) and EASA Acceptable Means of Compliance (AMC) appear to point to the quantitative values specified in the regulation for pilot flight control force. Furthermore, new cockpit flight control inceptors[[4]](#endnote-4) have been incorporated in most modern aircraft (e.g. side-sticks), beyond those specified in the tables of maximum allowable control forces as published in current regulations.

*Table 1*

Maximum Control Force for a Part 25 Transport Category Airplane-14CFR §25.143(d) and C.S. §25.143(d)

|  |  |  |  |
| --- | --- | --- | --- |
| Force pounds (newtons) applied to the control wheel or rudder pedals | Pitch | Roll | Yaw |
| For Short Term Applicationa for pitch and roll control-two hands available for control | 75(334) | 50(222) | ------ |
| For Short Term Applicationa for pitch and roll control-one hand available for control | 50(222) | 25(111) | ------ |
| For Short Term Applicationa for yaw control | ------ | ----- | 150 |
| For Long Term Applicationb | 10(44.5) | 5(22) | 20(89) |

aShort-term forces are the initial stabilized control forces that result from maintaining the intended flight path following configuration changes and normal transitions from one flight condition to another, or from regaining control following a failure. It is assumed that the pilot will take immediate action to reduce or eliminate such forces by re-trimming or changing configuration or flight conditions, and consequently short-term forces are not considered to exist for any significant duration. They do not include transient force peaks that may occur during the configuration change, change of flight conditions, or recovery of control following a failure

b Long-term forces are those control forces that result from normal or failure conditions that cannot readily be trimmed out or eliminated.

A similar chronology was followed for transport category Part 29 rotorcraft, whereby the pilot/limit control forces[[5]](#endnote-5) first published under CAR §7.225 in the 1950’s and subsequently converted to Federal Aviation Regulations under 14CFR §29.397 in the 1960’s have not changed, other than in 1977 when 14CFR §29.397 Amendment 29-12[[6]](#endnote-6) deemed the term “control wheel” as “unnecessary and also added forces for “secondary controls” with the explanation that the rule, as written, applied to all controls therefore a distinction needed to be made between "primary" and "secondary" controls (e.g. flap, tab, stabilizer, landing gear), such as provided for airplanes.

The current FAA rotorcraft flight control regulations, called limit pilot forces (i.e. foot controls-130 lbs, stick controls-100 lbs fore/aft and 67 lbs laterally), are written for the overall structural design loads imposed by the pilot in conjunction with any other forces from mechanical/servo assist. Hence, there is a lack of specific pilot flight control force requirements, in the context of pilot effort alone, beyond the vague statement of not requiring “exceptional pilot skill or strength”. The requirements for normal category Part 23 airplanes and normal category Part 27 rotorcraft mirror those of their respective transport category, other than normal category airplanes which include a “stick” control instead of a “control wheel” for pitch and roll.

Whereas in aircraft design, the anthropometric body measurements are typically bounded by the 5th and 95th percentile[[7]](#endnote-7), strength design limits for control forces normally only have a lower boundary, typically based upon the 5th percentile of the female user population (1st percentile for critical skills) or the weakest person in the population, as recommended in Mil-Hdbk-759C (1995). Over the years there have been some small-scale studies focused specifically on aircraft flight control forces, such as those conducted by Beringer (2006; 2007; 2008; 2009), Meyer, Pokorski, and Ortel (1996), McDaniel (1981, 1995), Hasbrook et al. (1972), Hertzberg and Burke (1971) and Kroemer (1971). However, there has not been any recent large-scale study of human strength/control forces for aircraft.

The pilot flight control maximum force requirements also touch other regulations, to include but not limited to transients in flight guidance systems (FGS), automatic pilot (AP) system malfunctions, trim runaways, and operation of variable inlet/exhaust geometry.

**The Way Forward**

To mitigate the hazard of excessive flight control forces and update the applicable FAA regulations to ensure that new aircraft designs account for the current pilot population demographic and flight control configurations, it is necessary to gather current data from a statistically significant and demographically representative sample of subjects. To that end, a study is currently being conducted by the FAA Civil Aerospace Medical Institute (CAMI) to gather valid flight control force-application strength data utilizing current and reasonably anticipated flight control-input devices to be found in transport category and normal category aircraft. A portable mock cockpit test rig is being used to collect data from volunteer subjects across the United States for momentary and sustained forces that can be exerted for a variety of inceptors (e.g. yoke, wheel, column, center & side sticks, cyclic, collective) when in the normal seated position with seat belt fastened and normal knee angles.

These data, scheduled to be available in early 2018, should be considered for mitigating the hazard of excessive pilot flight control forces by updating the FAA design certification regulations for airplanes and rotorcraft that are used by manufacturers to *show compliance,* and the FAA to *find compliance,* with regulations related to pilot flight control forces.

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1. The Aviation Safety Reporting System is administered by the National Aeronautics and Space Administration (NASA) through a memorandum of agreement with the FAA and was designed to encourage voluntary self-reporting by pilots of anomalous aviation events [↑](#endnote-ref-1)
2. Notice of Airworthiness Review Program No. 6; Notice No. [75-25](http://rgl.faa.gov/Regulatory_and_Guidance_Library/rgNPRM.nsf/2ed8a85bb3dd48e68525644900598dfb/759fc8554d8c6b8b852568b60068edfd%21OpenDocument); Issued on 05/29/75. [↑](#endnote-ref-2)
3. Notice of Proposed Rulemaking. Notice No. [94-15](http://rgl.faa.gov/Regulatory_and_Guidance_Library/rgNPRM.nsf/2ed8a85bb3dd48e68525644900598dfb/3007c2783ed1498685256923005a33b0%21OpenDocument); Issued on 04/11/94 [↑](#endnote-ref-3)
4. SAE ARP 6001 §2.2.1 Inceptors. A device that is used to provide pilot control inputs and covers a variety of aircraft pilot controls: side sticks, center sticks, pedals, engine controls and rotorcraft cyclic and collective controls [↑](#endnote-ref-4)
5. Pilot Limit Forces are the design loads that must be used in required structural tests and in any structural strength analysis of the control systems submitted in compliance with other rules as well as operation tests of the control systems noted in other rules. FAA AC 29.397 [↑](#endnote-ref-5)
6. Notice of Airworthiness Review Program No. 2; Notice No. [75-10;](http://rgl.faa.gov/Regulatory_and_Guidance_Library/rgNPRM.nsf/2ed8a85bb3dd48e68525644900598dfb/f2d74ab90baf8bde85256789006b8a22!OpenDocument) Issued on 2/27/75. [↑](#endnote-ref-6)
7. U.S. Federal Register- Airworthiness Review Program, Volume 40, Number 12, p. 24808, June 10, 1975 [↑](#endnote-ref-7)