AIRCRAFT DYNAMICS WITH INPUT DELAYS

(Romanian title: Dinamica avionului cu întârzieri în comandă)

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Flight control systems design continues to be one of the most demanding challenges in the world of automatic control. The magnitude of the problem is driven by the intrinsically nonlinear and uncertain nature of the tandem *controlled system* (i.e., the aircraft represented by its dynamics)-*control system* (i.e., the human pilot, and/or different flight control subsystems). In fact, any reasonable mathematical model of the human operator has to include in its structure the various psychophysical limitations in the human, finally concretized, among other things, as time delays. Position limitations and rate limitations of the servoactuators, as parts of the control loop, implicitly induce time delays. At last, due to the nonlinearities and inertia, the controlled system itself (i.e., the aircraft) induces also time delays in response to any input signal. To solve the problem, MIL-F-8785C Regulation expressly requires all these delays to be evaluated and included in an equivalent time delay of the couple controlled system-control system in order to decide about flying qualities of piloted airplanes. In terms of input-state-output space representation, when modelling the delay is introduced as input delay, or state delay, or output delay, or various combinations of these. Clearly, the delay injects exponential transcendentality to the characteristic equation associated to the linear systems. This results in infinitely many characteristic roots, thus making the stability outlook very complex. As many recent investigations state, the stability question of this class of systems is not fully resolved up to now.

This book is aimed to present a classical methodology in the analysis and the design of the systems modelled as having *input delay*, with raw material furnished by flight dynamics. The mathematical tools concern mainly the time domain apparatus of both Lyapunov stability methods: the method of first approximation and the method of Lyapunov function. The body of the book is composed by an Introduction, six Chapters, some Conclusions, and two Annexes and, of course, a Bibliographical section. Chapter 1 provides a concise statement of the problem of delayed systems and some considerations concerning the counteracting of time lag impact on aircraft dynamics by stabilization procedures and devices. The subsidiary method of singular perturbations offers to the author the machinery of splitting up the aircraft dynamics as slow-fast. The fast dynamics cannot be controlled by the pilot's signals and, consequently, need to be mitigated by stabilization augmentation systems (SAS). This is the theme of Chapter 2 (Mathematical modelling of aircraft fast dynamics), Chapter 3 (Synthesis of fast dynamics regulators) and Chapter 4 (Analysis of fast dynamics regulators). Two special methods for the study of the delayed systems are considered in Chapter 5 (The continuation method) and Chapter 6 (An optimization method with vectorial cost index). Annexes present general aircraft equations of motion, following famous Etkin's book, and the aircraft flying qualities criteria, taken over from MIL Regulations.

As concerning the Bibliography, this permits a paraphrase of the book title: we deal with a *delayed Bibliography*, until around the middle of '90s of the past millennium! The

explanation simply derives: probably, we deal with a text slightly updated based on author's doctoral thesis. Indeed, the references for some numerical applications and figures of the book concern INCAS/INCREST collective Internal Reports dated 1984, authored by the team T. Hacker, C. Oprisiu, A. Ionita.

Surveying the contents, the book appears to be a collection of techniques and results for aerospace engineering students and the practicing engineer who are already familiar with flight dynamics. First of all, the book surely will serve in the role of further takeover of the various mathematical models of aircraft dynamics as kickoff for laborious nonlinear analysis studies involving fashionable paradigms (Hoph biffurcation, pilot-induced oscillations-PIOs and so on …)

Unfortunately, the text is not exonerated of hilarious formulations ("…este de mentionat *aportul adus* de T. Hacker.", pg. 10; "… al doilea caz consta in considerarea deficientelor *aprioric de la inceputul* proiectarii sistemului.", pg. 11 etc.) or frequent grammatical disaccords ("… transportul caldurii in materialele cu memorie *au* la baza modelele de ecuatii …", pg. 11; "… un scurt istoric asupra criteriilor de apreciere *ale* calitatilor de zbor", pg. 16 etc.)

With undercurrent deference, I'm however saying that the block "COMENZI PRIMARE" in Fig. 1.1 is devoid of content. Writing the magic word "demonstration" as on the pages 88, 92, is devoid of content. The book title itself, "…intarzieri in comanda" (the English version of the title is thought out by the undersigned), is at least arguable, if not ambiguous. The English term "command", in the IFAC control terminology, is consecrated to "reference signals" (the operating point control references). It is true, the Romanian terminology in the field uses yet (and abuses of) the notion "*comanda*" instead of "*control*", often without the definition of the context. Or, given the context, herein the point in question is rather the term control, and not command (reference), because, in fact, the control signals, in a control loop, are those which are subjected to time delays.

Beyond these shortcomings, let us congratulate the author for this book, which fills a niche in the flight dynamics literature for our students and researchers.

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