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Flight tests and flight data analysis—Teaching aerospace engineering students

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Abstract

The ability to carry out in-flight tests and to analyse the flight data registered is, in the case of aerospace engineering students, a vital aspect of education. Since aircraft flight tests are very expensive, frequently the funds allocated to them in the process of education are insufficient. The aim of this article is to present a relatively low-cost method of training students to carry out flight tests and to analyse flight data. The method relies on three consecutive steps. At first, simulation tests relying on the mathematical model of an aircraft are carried out. During these simulations, students analyse the aircraft behaviour. Next, flight data registered during previously held in-flight tests are analysed. Finally, flight tests are performed by students. As a result, having mastered the ability to analyse real flight data, the students trained will become high-class specialists being able to conduct flight tests and analyse flight data.

Keywords: Flight testing, flight data analysis, aerospace engineering education.

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1. Introduction

The ability to carry out in-flight tests and to perform flight analysis is vital for a graduate of aeronautical engineering studies. Flight testing is conducted in order to test new constructions, new avionics and control systems, measurement instruments, etc. In the field of aerospace engineering, new methods are constantly being developed to simplify the flight testing (Boden, 2013; Rzucidlo et al. 2015; Kopecki & Rzucidlo, 2015). Also, research in the area of aviation (Kopecki & Rzucidlo, 2008; Kopecki & Rogalski, 2014; Mystkowski, 2013; Spiegel, Kriegel, Dambeck, Holzapfel, 2015) requires flight testing. The ability to analyse the registered flight data is used both during the flight tests, as well as for the monitoring of airline flights. Due to such analyses, abnormal conditions which may lead, for example, to aircraft damage can be detected, and hence flight safety is increased. Flight data are also analysed after aviation incidents and accidents, as the analysis is helpful in the determination of causes of air disasters (Witkowski, 2013). For all these reasons, it can be assumed that the ability to analyse flight data is essential for a thorough education of graduates in Aeronautics and Space Technology. Unfortunately, flight tests are extremely expensive, and the budget allocated for university education is, not infrequently, insufficient. This article is intended to show how to teach to abilities described above relying on a relatively low-cost didactic process.

2. Analysis of data recorded during simulations

Experience shows that at the beginning of education students find it difficult to interpret diagrams showing basic flight parameters and observe data dependency. Therefore, at first, students interpret flight parameters recorded during computer simulations. The parameters are derived from typical manoeuvres performed with the use of flight control systems. Alongside with making interpretations, students become acquainted with the operation of flight control systems. They analyse the structure of control algorithms and create performance charts for typical flight parameters. For example, the aim of a typical exercise is to control the roll angle. Figure 1 shows a simplified roll control system. Aircraft dynamics is modelled on the basis of a linearised aircraft model. Servos, receiving desired data from the roll angle controller, initiate the aileron deflection. The desired roll angle is compared with the roll angle measured. Figure 2 shows a typical set of parameters obtained during simulations. Diagrams obtained during simulations allow us to observe the data dependency. For example, during a normal turning flight the roll angle is correlated with heading and yaw rate (Figure 2). These dependencies are clearly evident from the analysis of diagrams. Obviously, simulations only are not sufficient. Additionally, real data are burdened with measurement noise and other types of disturbances or failures. Consequently, the next step is to analyse data registered during flight.

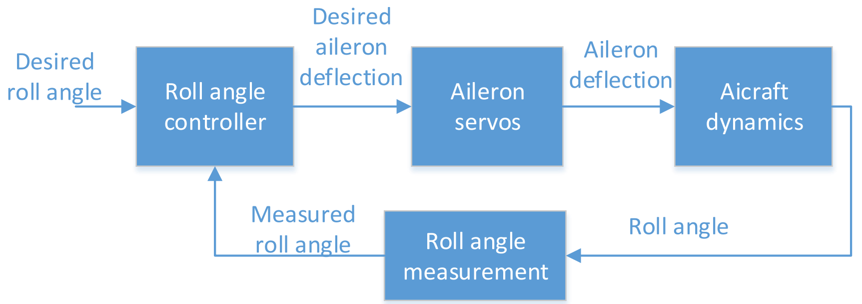

Figure 1. A simplified roll angle control system

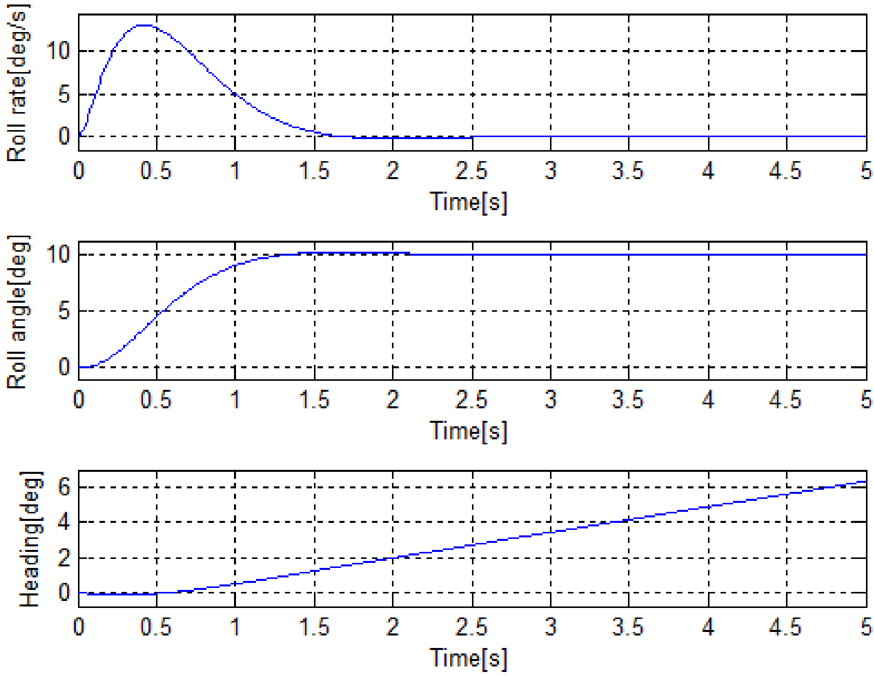

Figure 2. Parameters, obtained during simulations, characterising the aircraft lateral motion

3. Analysis of data recorded during earlier flights

Students can learn how to analyse flight data on the basis of previously held flights. This is, in fact, a very good didactic method. It has to be remembered, however, that at the beginning students should be provided only with chosen data for a given manoeuver. Such an approach will teach students an off-line analysis of flight data. Unfortunately, due to limitations in the number of hours assigned for a given course at the University, the realisation of the described aim has to take place during different courses. For instance, students are given a few sets of data registered during earlier flights. On the basis of these sets, they generate appropriate diagrams. Next a certain task is assigned, such as, for example, identification of a given parameter. In this way, students gain preliminary insight into real data analysis. The analysis of the whole flight can follow as the next step. This will teach students to recognise characteristic phases of flight which require a more detail analysis. Due to the skills acquired during such a didactic process, after graduation students will be able to analyse flight data, what is useful, e.g., for different aircraft operators or during investigations into the causes of aviation accidents.

Figure 3 shows an exemplary distribution of data recorded during a test flight. On the basis of the above data distribution diagram, students are able to assess whether the data were recorded properly (they can compare the roll rate with roll angle and accelerations during flight). Next they can determine parameters of the dutch roll motion of the aircraft (damping ratio, the period and frequency of oscillations).

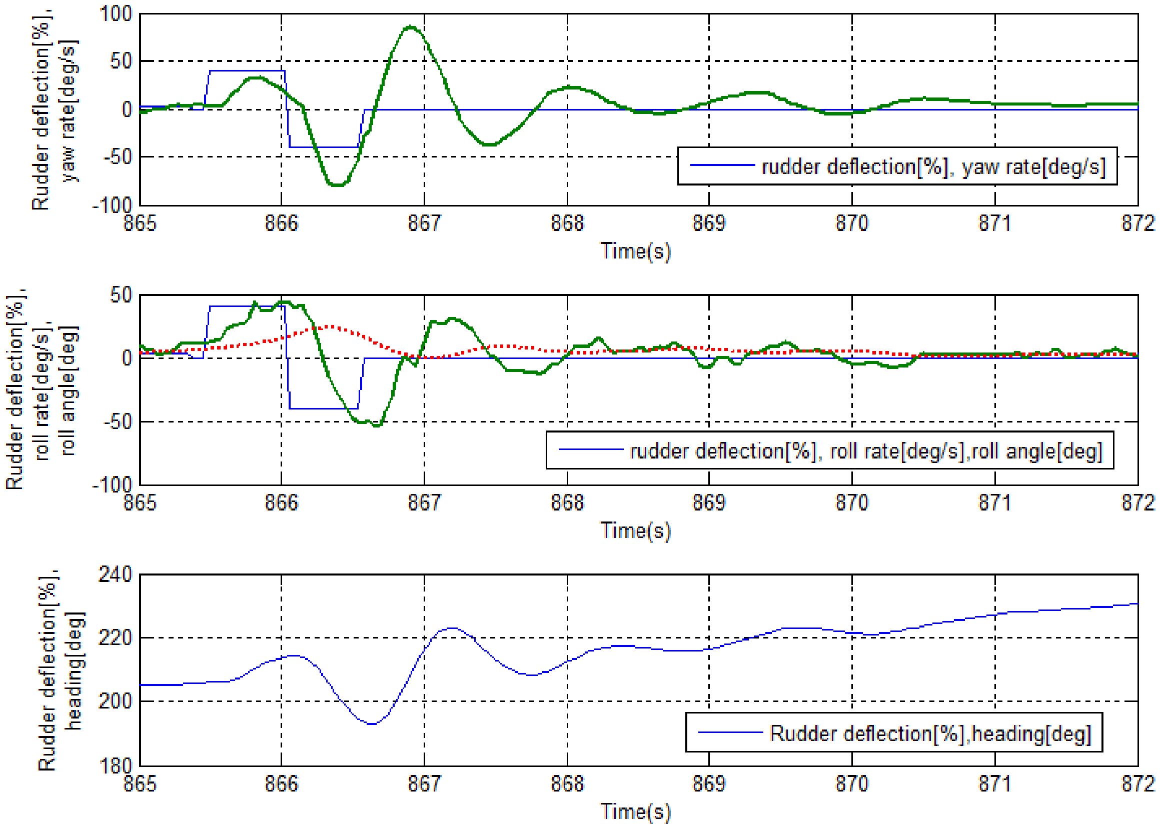

Figure 3. Distribution of data recorded during a test flight

Analyses of real data are a vital element of the didactic process. Due to such analyses, students become familiar with different systems of data analysis, as well as they are ready to broaden their knowledge in this field. Real flight testing follows as the next step.

4. In-flight testing

Due to different time, as well as organisational or financial limitations, the in-flight tests carried out either on manned or unmanned aircraft are not always possible during the educational process conducted on many technical universities educating aerospace engineers. The analysis of simulation data described above, as well as the analysis of data recorded during earlier flights are both important steps in the education of future aerospace engineers. Nevertheless, by taking part in the preparation of a test plan, as well as being directly involved in flights, students undoubtedly gain additional practical skills. In order to simplify students' participation in flight tests at the Rzeszów University of Technology, an on-board system for data measurement and automatic flight control in different types of aircraft, developed in the frames of the research project 'Methodology of control system synthesis taking into consideration higher risk situations', will be implemented in the didactic process in the near future. The system, shown in Figure 4, includes a control computer together with a measurement unit and a radio modem enabling wireless communication. Importantly, it can be used for both manned and unmanned aircraft, which is its unquestionable advantage.

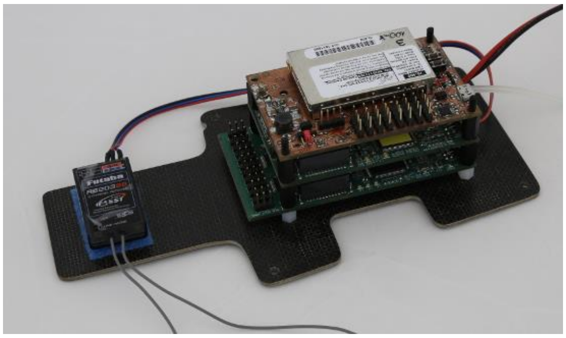

Figure 4. Control computer with a measurement unit and a radio modem

Since the article does not aim at the presentation of technical solutions, a detailed description of the architecture of the system is not presented here. The architecture is going to be described in other papers, currently under preparation. Broadly speaking, the structure is open and it is based on a CAN data bus. If necessary, it can be easily extended to include redundant elements, like, for instance, additional measurement units. Preliminary tests of the system show that it is useful both in education and for research purposes.

Due to the involvement in real flight tests, students do not only become familiar with technical aspects of tests, but additionally, since they have to take responsibility for the whole task, their social competence is enhanced. Irresponsible behaviour may have serious or even fatal consequences for human health; it may also lead to property damage. For these reasons, very high requirements are set for every flight test. The flight test is prepared and conducted as follows:

1. Tools necessary for the flight test are prepared. For this stage, a simulation stand is used. This allows students to become familiar with: software used in the autopilot, operator interfaces and analysis of the recorded data.
2. Direct preparation for the flight on a manned or unmanned aircraft takes place. Students prepare a plan for the experiment, they check the equipment and software in the aircraft. They inform the pilot of a manned aircraft or the operator of an unmanned aircraft about the plan prepared.
3. The flight test is conducted. Students are supervised by a tutor; special attention is paid to safety rules and to correct preparation of flight documentation.
4. Description of recorded data files. In order to facilitate, or even enable, the data analysis, it is necessary to create an after-flight documentation including the description of the flight test.
5. Analysis of recorded data is conducted and a report is prepared.
6. On the basis of the data recorded, an analysis is conducted and a report from the task realisation is written.

It is worth noticing that due to the unification of hardware and software in the system used, the flight tests can be easy conducted on different types of aircraft, which are family of flying laboratories (Tomczyk, 2010), such as a UAV, an ultralight airplane or twin engine general aviation aircraft. The use of UAVs contributes to the reduction of costs. What is more, working with UAVs students become acquainted with procedures to be applied in unmanned systems, as well as they learn how to control the ground station.

In the case of the ultralight airplane, it is possible to implement control algorithms, as this airplane is equipped with a servomechanism compatible with the presented control system. An hour of flight with the ultralight aircraft is relatively inexpensive, which is an unquestionable advantage for the academic setting. However, it has one important disadvantage making some tests impossible, namely, it is a two-person airplane. It has to be remembered, however, that the organisation of a flight test is not the same as conducting a flight test. Preparation of the test plan, participating in the preparation of the aircraft for the flight or observation of the flight from the ground position using the ground station or telemetric systems (Rzucidlo, 2012) are all important aspects of the education of specialists in aeronautical engineering.

Instead of an ultralight airplane, the twin engine aircraft can be used for the educational purposes. This is a six-person airplane, so, in addition to the pilot, five students can directly participate in the flight test. Nevertheless, the cost of an hour of flight with twin engine aircraft is relatively high.

5. Summary

Flight testing is an important phase of the development of any new aircraft, and methodology for conducting flight tests is constantly being refined. The goal is to increase the efficiency of flight testing and, at the same time, reduce costs. Flight testing would not be possible without well-educated aeronautical engineers. What is more, gaining practical experience in conducting flight tests is also valuable for engineers who are only indirectly involved in flight testing. Being aware of what is technically possible and knowing technical limitations, they prepare testing requirements which are feasible in practise.

It is also essential that an aeronautical engineer is able to analyse data recorded during flight. In accordance with methodology described in this paper, at the beginning of the training students analyse data collected during simulation tests; later, they proceed to the analysis of data recorded during real flight tests.

The acquired ability to analyse data recorded during flight tests will be useful for their future jobs in which they will be expected to supervise the operation of aircraft or during investigation of aviation incidents, accidents and other air disasters.

The tasks described in this article are used as supplementary material for such courses taught traditionally to future engineers in aeronautics. It is believed that students who receive a broad education in the theory of aviation combined with practical aspects will, in the future, become top-class engineers.

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