Identification of the operational characteristics of non-autonomous unmanned aerial vehicles for the purpose of operating in controlled airspace

Abstract

The doctoral thesis raised the problem of integration of unmanned non-autonomous aircraft in controlled airspace. The aim of the study was to determine the performance envelope and design features of RPA that meet the requirements of integration with manned aviation in the uniform airspace. The object of the research were small and medium unmanned airplanes (MTOM = 25-450 kg). Differences in RPA performance relative to manned aircrafts have been identified. Research on the impact of the presence of RPA on manned air traffic and the possibility of integration in procedures designed for manned aviation was done. Departure and approach procedures from controlled airports (SID and STAR) were selected as a critical element of the controlled airspace due to descent, climb, level flight segments and different maneuvers.

The problem was described in terms of system analysis and the system composed of RPA-SID/STAR-atmosphere was isolated. The models of RPA characteristics and SID/ STAR procedures were built. The RPA model included flight trajectory, steady flight performance, airframe geometry, aerodynamic characteristics, power unit, masses and loads. The minimum number of three decision variables of the RPA model were determined, i.e. take-off mass, wing loading and power loading. The model of the SID and STAR included the procedural trajectory and the area of tolerance. The reference shape of the procedural trajectory was determined using the statistics of the existing procedures and the guidelines for designing procedures. The research method used was fast-time simulation (FTS). This enabled to study various RPA variants in different procedures and wind conditions. Simulation software was built in the Matlab environment, in which RPA, SID and STAR models were implemented numerically. Integration performance indicators (PI) and assessment metrics have been defined in two areas of ATM development, i. e. safety and efficiency. The metric for the safety assessment was to follow procedural trajectory by RPA (relative position). The efficiency assessment included two metrics: the RPA flight time in relation to a manned aircraft in the SID and STAR execution and the compliance with the aircraft speed category of the A (according to ICAO).

The result of the work was the identification of the operational characteristics envelope of RPA in the SID and STAR execution - flight time, flight speed and the way of the procedural trajectory execution. The results were presented as areas of integration as a function of decision variables in the form of graphs and mathematical relationships. The key decision variables were the wing loading and the power loading, while the take-off mass conditioned the integration to a lesser extent. Critical segments of procedures were indicated – final approach and initial climb. The critical crosswind speed was determined. The impact of wind speed and directions in different types of procedures was assessed. Approach procedures with a turn and racetrack manoeuvres showed the smallest discrepancy in RPA performance compared to a manned aircraft in various wind conditions. The simulation results were synthesized defining the RPA integration area. The boundary of the integration area was determined by the criteria of impact on manned air traffic and the ability of executing the flight trajectory. The RPA variants within the integration area also met the criteria of speed category A. Direction for further works were proposed - research on complex air traffic or adjusting procedures to RPA performance.

In comparison with similar studies, the result of the work contributes to the integration problem as the usual RPA performance was assumed on the basis of a small number of known objects and the procedures were modelled in terms of trajectories without tolerance areas.

***Key words**: RPAS integration, RPA performance, flight trajectory, fast-time simulatuions FTS, SIDs and STARs procedures, uniform airspace, controlled airspace*