FLIGHT TEST VALIDATION OF PBN CONCEPT OF OPERATION IN TERMINAL AREA IN SIMULATED ENVIRONMENT

ABSTRACT

The Performance-based navigation (PBN) concept defines requirements for navigation specifications on which instrument flight procedures are designed. The results of standard instrument arrival procedure flyability testing based on the RNAV-1 navigation specification at Dubrovnik terminal area are presented. The use of these procedures was demonstrated in a simulated environment. The methodology established can be useful contribution for further development and possible improvements in airspace concept design.

KEY WORDS

performance-based navigation; navigation procedures; flight test

1. INTRODUCTION

Performance Based Navigation (PBN) is a framework for defining performance requirements in navigation specifications that contain detailed aircraft and operator or pilot requirements [1]. It defines a set of standard airborne and ground functional requirements also for navigation applications, and infrastructure. The new ICAO PBN concept requires a unified airspace classification. This airspace classification is also applied to terminal areas and is a basic prerequisite for the PBN procedure implementation. An additional requirement is the development of a National plan for PBN implementation along with airspace concept clearly defined at a strategic level. The National Plan is an umbrella strategy document, which defines the short, medium and long-term goals for implementation of the selected PBN navigation specifications. These specifications will meet operational requirements of airspace users and other requirements concerning environmental protection, and will increase safety and capacity of airspace. The PBN implementation steps are defined by ICAO and should be accepted by the National authority. As by 2017, the guidelines for the implementation of PBN were not defined through the umbrella strategy document in the Republic of Croatia, Croatia Control Ltd. applied internal expertise and the common practice according to which Eurocontrol member states define the airspace concept for PBN implementation.

In this paper, the research results of future standard instrument arrival route/procedure at Dubrovnik terminal area (TMA) are presented. Ground validation of instrumental flight procedures included obstacle clearance, trajectory calculation, coding and charting. Simulator validation, as next step in procedure validation process according to [2] aimed at high level quantitative assessment of manoeuvring and database validation. The objective of the flight/simulator evaluation was to assess...
flyability to determine that the procedure can be safely flown, and to evaluate other operational factors. The arrival routes were based on the RNAV-1 navigation specification for aircraft category A and B. An aircraft flight simulator (FNTP Type II) was used as a model to determine the fuel consumption (fuel burned) and flight time of the King Air 200 aircraft. The procedures were designed, programmed into simulator’s guidance computer, and a series of test flights were carried out. The objective of the research was to demonstrate the possibility of manoeuvring an aircraft within the flight envelope according to the proposed scenarios. The scenarios were defined upon the anticipated traffic situation. The flyability of the instrument flight procedures was demonstrated and the obtained results will be used for further development and possible improvements prior to the PBN implementation.

2. AIRSPACE ANALYSIS

In conventional navigation, open loop radar vectors (tactical vectoring) included heading instructions are common used method for merging and handling arrival traffic flows. Moreover, standard instrument arrivals (STARs) based on conventional procedures could be used for handling the traffic where aircraft should follow a route which is described by ground navigational aid [3]. PBN concept capitalize on the enhanced navigation capabilities of aircraft avionics and represents the shift from conventional navigation with Global Navigation Satellite System (GNSS) as primary sensor. For arrivals, it reduces the vectoring of aircraft in terminal areas to the final approach and from the runway to the terminal area boundary for departures. Additionally, voice data analysis results show up to 40% reduction in the amount of two-way communications and up to 50% reduction in the amount of information required [4]. The PBN implementation plan includes the definition of adequate navigation specifications according to airspace concept. Therefore, an airspace analysis of TMA Dubrovnik was carried out. The analysis was based on the comparison of actual and planned traffic. The Communication Navigation Surveillance (CNS) equipment and aircraft capability were analyzed and linked with available CNS functionalities of Air Navigation Service Provider (ANSP). The analysis showed that there is room to improve the level of service by upgrading new and optimizing existing operational procedures. This would improve safety and create preconditions for an increase in airspace capacity and overall flight efficiency. Additionally, the procedure was constructed according to the ICAO Manual PBN for Dubrovnik Terminal Control Area. The use of the Standard Instrument Departure and Standard Arrival Route (SID/STAR), according to the RNAV-1 navigation specification, was also defined. Inadequate coverage of the ground-based Distance Measuring Equipment (DME) station signal in the TMA jurisdiction disables the integration of DME/DME procedures that can be used as back-ups in the event of the GNSS signal loss. The GNSS is a primary sensor for the specified RNAV-1 navigation specification. Therefore, it is necessary to define operational procedures and instrument flight procedures so that an aircraft as a secondary procedure can follow the conventional and available SID/STAR procedures to ensure safe operation during an entire flight. An expert analysis established that the existing operational procedures, related to coordination with other terminal zones, do not adversely affect safety, capacity and flight efficiency. On the contrary, the implementation of the PBN and co-ordination agreements with other providers have a great potential for further improvement.

The trend of air traffic growth at all airports in the Republic of Croatia has been steadily increasing. It is predicted that it could reach up to 5% per annum. The efficient planning of flight operations is limited by the existing instrument flight procedures based on conventional navigational ground-based radio aids (VOR, NDB). In the long run, that might cause operational problems in TMA’s because the currently used conventional procedures are specifically designed for non-instrument runways and not flexible for the adaption of future traffic situations. Regardless, during the temporary regulations on air traffic during the peak season have been introduced based on the maximum capacity of the airport rather than those of terminal airspace.
3. CHANGE IN CONCEPT OF OPERATION

The implementation of the PBN concept in TMA includes the design, publication and operational use of an entirely new organizational concept of airspace. This primarily applies to the PBN SID/STAR navigation routes. Furthermore, these routes need to be operatively linked to approach procedures that are also based on PBN (RNP APCH) concept, for all instrumental runways. This applies also to those runways that are not technically equipped with instrument landing system. Simulation results in advanced arrival management technologies indicates achieved benefits by enabling PBN. Flight path predictability improved, arrivals flew more fuel-efficient descents for longer time and self-reported controller workload was reduced [5]. The change in concept of operation applies to optimization of traffic flows, thus increasing the predictability of flying operations. Predictability reduces air traffic controller workload and operating costs of airline companies along with fewer emissions of the exhaust gases into the atmosphere. To achieve optimization, it is necessary to create, publish and operationally use the PBN concept that will connect the SID/STAR navigation routes and instrument approach procedures. It is therefore necessary to design and publish the RNP APCH procedures that will also provide vertical guidance.

It was shown that an increase in the maximum allowed flight path angle could result in substantial fuel savings [6]. An important element that emerges from the scope of increasing operational capacity in the airspace is the creation, publication and operational use of CDA/CDO/CCO (Continuous Descent Approach/Continuous Descent Operations/Continuous Climb Operations) for all airports/runways in TMA. The operational use of these procedures cannot be implemented without implementing the PBN concept, although they are now to some extent operationally applied at a tactical level. By application of the PBN, arrival and departure procedures would be designed in such a way that aircraft are laterally and vertically separated. This, in addition to reduced fuel consumption and exhaust emissions, has a positive effect on the air traffic controller workload.

4. METHODOLOGY

The impact of introducing PBN instrument navigation procedures on air traffic flow in TMA, has to be tested on the entire Croatian flight information region (fast-time and real-time simulations). It is also necessary to determine the effects of the PBN concept on existing flexible-use-of-airspace (FUA) procedures according to which all safety prerequisites should be taken into consideration and kept at least at the same level as before the PBN implementation.

The purpose of this research was to prove that the present aircraft could safely follow the proposed RNAV-1 arrival procedure in Dubrovnik TMA in various scenarios that may depend on the actual traffic situation. In addition, the possibility to achieve smooth transition from the arrival procedure to the conventional approach (ILS) procedure was considered. Based on this, the scenarios that defined the aircraft’s flight path according to the defined waypoints in the RNAV-1 STAR procedure for runway 12 at Dubrovnik Airport (ICAO code LDDU) were elaborated (table 1).
Table 1 – Various traffic-based scenarios for PBN RNAV-1 arrival procedure for runway 12 at Dubrovnik airport

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Aircraft trajectory according to waypoints</th>
</tr>
</thead>
</table>

The navigation procedure and the corresponding scenarios shown in table 1 were based on the test RNAV-1 STAR for RWY 12 LDDU proposed by Croatia Control according to [7]. Additionally, the design of proposed test procedure was based on actual flight tracks based on conventional STARs in TMA Dubrovnik (figure 1).

Fig 1. Usual flight tracks in TMA Dubrovnik based on conventional procedures

In terms of determining flight efficiency provided by the PBN concept, fuel consumption for the aircraft was determined in the specific flight regime under ISA conditions. The basis for the calculation was a King Air 200 airplane with 5620 kg operating mass. The flight speed was 170 kt (at 170 RPM), which was reduced to 140 kt during the approach phase of flight. The navigation procedure RNAV-1 was incorporated into the Garmin 430 GPS flight plan. Each flight plan executed according to a predefined scenario and the aircraft simulator was programmed to follow the defined flight path. During the test flights, the time of overflying of specific waypoints and the fuel condition were recorded. Thus, the total flight time in each scenario and the total fuel consumption of the aircraft were determined from the start of the arrival procedure to the landing.
5. RESULTS

All arrival scenarios were based on same power settings with the same amount of fuel at the initial approach fix (IAF). The IAF was a starting point for arrival procedure. Flight time and fuel consumption were monitored from TIKSA point from initial altitude of 5000 ft. The descent and approach phase of flight started at PILAP waypoint, with recommended rate of descent of 700 fpm. At distance od 3 NM from the runway 12 threshold, speed was reduced to 130 kt and landing gear was extended. Table 2 shows flight times and fuel burned for each of the individual scenarios.

Table 2 – Flight times and fuel burned for different scenarios in TMA Dubrovnik

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Total flight distance [NM]</th>
<th>Flight time [min]</th>
<th>Fuel burned [kg]</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>49,6</td>
<td>17,31</td>
<td>72,9</td>
</tr>
<tr>
<td>B</td>
<td>81,7</td>
<td>26,19</td>
<td>114,3</td>
</tr>
<tr>
<td>C</td>
<td>109,7</td>
<td>35,1</td>
<td>162,5</td>
</tr>
<tr>
<td>D</td>
<td>95,7</td>
<td>30,5</td>
<td>147</td>
</tr>
<tr>
<td>E</td>
<td>76,7</td>
<td>24,54</td>
<td>113,4</td>
</tr>
</tbody>
</table>

Aircraft flight trajectories are recorded in a simulated environment according to individual scenarios describing all possible traffic situations in TMA Dubrovnik (figure 2).
Data from table 1 and trajectories from figure 1 could be used for operational planning in terms of additional fuel needed if the one of possible detected scenario is in effect in TMA. Thus, data could be useful in defining controller operational procedures in traffic separation. Additionally, controller workload can be tested and compared on those scenarios and possible routing.

4. CONCLUSION

In this paper, the results of instrument arrival flight procedure flyability testing, based on the RNAV-1 navigation specification, at Dubrovnik TMA are presented. It is shown that the aircraft can follow a navigation procedure for aircraft category A and B based on the PBN concept (RNAV-1). The waypoints based on GNSS rather than conventional radio navigation aids are suitable for defining the aircraft flight path in the terminal area and can be used to create a flight plan in the aircraft navigation system.
From an operational point of view, some deviations from a defined arrival procedure are possible. Those deviations are a result of the specific traffic situations which are presented in the paper as five different scenarios. In each of these scenarios, the aircraft following the flightpath defined by the waypoints can perform safe turns with specific radius combined with change of altitude. According to the defined constant flight speed, the safe maneuverability while maintaining safe envelope was achieved. The transition of the arrival procedure to the approach procedure in all five scenarios was accomplished without difficulty and influence on the flight safety. It can be concluded that the procedure design and overall concept correspond to the PBN criteria and application, and are suitable for further development. The results obtained by research can be used to evaluate the application of each scenario on a specific aircraft in terms of flight duration that directly corresponds to airspace capacity of the TMA. Additionally, the difference in fuel burned according to each scenario is an indicator for an airline for forecasting the required fuel for the flight, which, among other things, is calculated according to the operational limits imposed by the ATM. The use of these procedures was demonstrated in a simulation environment. The methodology established can be used for further development and possible improvements of operational concept in terminal area. A further test of concept of PBN operation should be carried out prior to the implementation of approved PBN procedures.

REFERENCES