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Three-Degree Decelerating Approaches in High-Density Arrival Streams

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Trajectory unpredictability of aircraft performing continuous descent approaches results in reduced runway capacity, because more spacing is applied. A possible solution to this problem is self-spacing: the transfer of the spacing task from the controller to the pilot. Using a fast-time simulation tool, the performance differences between distance- and time-based self-spacing in high-density traffic in terms of runway capacity and separation are quantified for the three-degree decelerating approach. Distance-based self-spacing is the most promising concept. The average runway capacity is 39 aircraft per hour (40% heavy, 60% medium aircraft). Runway capacity in the case of time-based self-spacing is 3 aircraft per hour lower, due to spacing margins applied to lower the separation violation rate to the level of distance-based spacing. A sensitivity analysis was carried out for distance-based self-spacing. One of the results is that accurately determining the starting time and subsequently arriving at this time benefits the three-degree decelerating approach performance. Three-degree decelerating approach performance is also affected by the initial speed and altitude, as they affect the three-degree decelerating approach's control space.

I. Introduction

CONTINUOUS descent approach (CDA) is a cost-effective means of reducing aircraft noise, emissions, flight time, and fuel burn [1–4]. Aircraft continuously decelerate while on these approaches, which leads to trajectory unpredictability from the standpoint of a controller who is monitoring interaircraft spacing based on periodic radar updates of aircraft position. As such, controllers apply larger spacing to prevent vectoring instructions that would conflict with the CDA. Larger spacing between aircraft reduces runway capacity down to 50% when compared with conventional approaches [5–8].

A possible solution to this problem is the use of in-trail self-spacing [6,7]. The spacing task is transferred from the controller to the pilot. Self-spacing is proposed because of the availability of precise aircraft performance information and the control strategy onboard the aircraft. The maneuverability of an aircraft while executing a CDA is limited and driven by the aircraft performance, the control strategy, and wind conditions. Information about wind conditions that the aircraft is likely to encounter during descent can be made available as described in [9]. The flight crew can plan and execute, with the help of onboard systems, a CDA to remain safely separated [10–12].

This paper discusses research into the performance of the three-degree decelerating approach (TDDA) in high-density arrival streams in a distance- or time-based self-spacing environment. The TDDA is a CDA that lies within the boundaries of present approach procedure limitations and gives the pilot control over the descent path to fulfill the spacing task [6,9–13]. In a distance-based self-spacing environment the aircraft actively adapts its speed profile to the speed profile of the aircraft flying directly in front. This requires that the aircraft predicts the trajectory of this leading aircraft. Using the relative state of the leading aircraft to predict the trajectory can give rise to transient motions in the arrival stream, hereafter referred to as the "slinky effect," resulting in spacing problems [14]. In this research, intent-based trajectory prediction is introduced for the TDDA to prevent the slinky effect in the case of distance-based self-spacing. Another solution to circumvent the slinky effect is a time-based self-spacing procedure, which does not require trajectory prediction of the leading aircraft during the TDDA [9]. Its performance was compared with the more common distance-based procedure. In the time-based environment the aircraft receive a required time of arrival (RTA) for the runway threshold point. The RTA are set before the start of the TDDA with the aim to keep the aircraft safely separated during approach. A fast-time simulation tool was developed to investigate the differences in performance between distance- and time-based self-spacing in terms of capacity and loss of separation.

II. Three-Degree Decelerating Approach

A. Description of the Procedure

The TDDA is a straight-in approach, with a constant 3 deg geometrical path angle [13]. Figure 1 illustrates the TDDA together with a conventional step-down approach. The approach procedure starts when the aircraft intercepts the fixed descent path at an altitude (7000–10,000 ft) well above the altitude that the aircraft intercepts the instrument landing system's glide slope. Initially, the aircraft maintains a constant indicated airspeed (IAS).

To perform the spacing task, control over the descent is required. The TDDA gives the pilot two controls. The first control option is the thrust cutback (TCB) altitude, in which engine thrust is set to idle and the aircraft starts to decelerate. Moving the TCB altitude up results in a slower descent and moving the TCB altitude down speeds up the descent. The second control option available after the TCB is flap scheduling. After the TCB, the aircraft starts to decelerate. By changing flaps speeds, the pilot controls the deceleration of the aircraft along the flight path. During the TDDA the pilot performs two tasks. One task is the spacing task in a distance-based or time-based self-spacing environment. The second task is to bring the aircraft in a stabilized landing configuration at the 1000 ft reference altitude h_{ref} at approach speed V_{app} for safety reasons. Below h_{ref}, the aircraft maintains V_{app}. Reaching V_{app} above h_{ref} is not desired

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