ABSTRACT

The Steep Segmented Approach has been considered as a way reducing aircraft noise in densely populated areas. Therefore, this procedure with a steep segment of a 4.0° approach angle followed by a second segment with a conventional 3.0° approach angle has been subject of research at Cologne/ Bonn Airport, Germany’s third largest freight airport. Following last year’s SITRAER-paper of flyability studies and preliminary estimates of noise, results of test flights are going to be discussed, which have been performed by two airlines in September 2016. During the test flights, advanced noise measurements were conducted close to the approach path.

**Keywords**: Aircraft Noise, Steep Segmented Approach, Noise Abatement, Noise Abatement Flight Procedure, Test Flights.
1. INTRODUCTION

The motivation for optimizing flight trajectories is including two reasons. On one hand, reducing the fuel burn is desired especially by airlines. Local residents living close by the airport on the other hand are aiming a mitigation of the noise impact. The recent report “Analysis of vertical flight efficiency during climb and descent” by Eurocontrol [EUROCONTROL 2017] shows the relevance of (vertical) profile optimization in the present research landscape.

As being part of the area of vertical flight optimization, the Steep Segmented Approach is focused on mitigating the noise impact. By increasing the distance between the emitter (approaching aircraft) and the receiver (population) the noise received is greatly affected. The fundamental principal as well as preliminary results on a flyability study have been presented on last year’s SITRAER conference [SCHULZE SCHWIENHORST 2016].

In September 2016, almost a dozen test flights on this procedure were conducted at Cologne/Bonn Airport. Aim of the test flights was to validate and prove the results from the flyability study and simulations within the INM.

The subsequent chapter will present the fundamental rationale behind the concept of flying a steeper than normal approach in a condensed way. Furthermore, results of the flyability study as well as estimations on the noise impact will be called to mind again. Following the revision, the results for TUIfly test flights will be presented and discussed.

2. THEORETICAL FRAMEWORK

In preparation of the actual test flights, an approach profile for EDDK was designed and flight as well as noise simulations were performed. As this preparational framework was discussed in detail before [SCHULZE SCHWIENHORST 2016], a brief summary of the former activities will follow at this point.

2.1. Procedure Design

The general layout of the approach profile at EDDK is shown in Figure 1. The DLR Institute of Flight Guidance was mainly responsible for this design, which was based on former tests at airports in Germany such as EDDF or EDDV [MOLLWITZ 2014].

![Figure 1: General Layout of the Approach Design](image)
The angular path of the approach profile is defined by the three waypoints DKS02, DKS01 and RW32R leading to a landing at runway 32R at Cologne Bonn Airport (see Figure 1). The angle of descent of the “steep” segment between DKS01 and DKS02 was defined in a range between 3.5° and 4.5°. The angle of the segment between RW32R and DKS01 was fixed to 3°. While the start of the steep segment at DKS02 was set to 10,000 ft MSL, the switch to the 3°-segment was set to 2000 ft MSL. So the distance between DKS01 and the runway threshold was constant at 5.2 NM and the distance between DKS01 and DKS02 was dependent on the varying angle of descent.

2.2. Flight Simulator Testing

The just described Steep Segmented Approach procedure was tested in a flyability study by both the UPS Chief Pilot Group and TUIfly. The DLR Institute of Flight Guidance as well as Boeing’s Airport Noise Analysis & Flight Procedure Branch and the FAA’s Environment and Energy Section contributed their expertise to the flyability study. As flight simulators, B737-800, B767-300W, and MD-11 were used. The simulator trials were conducted in November 2015 and January 2016. Within the trials, different angles and weather conditions have been investigated. For the B737-800, a Full Flight Simulator was used and approaches have been inserted manually in the FMC using altitude constraints and user defined waypoints. For B767-300W and MD-11, the initial testing and analysis were conducted at the UPS Flight Training Center in Louisville utilizing UPS Full Flight, Level D Simulators. In the simulator trials, the approach angles of 3.50, 3.75, 4.00, 4.25 and 4.50 degree were applied for the steep segment between DKS01 and DKS02. Variables used in the testing included the aircraft landing weight, wind speed, temperature, aircraft centre of gravity as well as engine anti-ice. Furthermore, a “worst-case scenario” with heavy landing weight, higher than standard temperature (ISA +10) and tailwinds throughout descent and landing was defined.

The results of the simulator trials showed that all aircraft were capable of flying a dual-segment approach with angles of up to 4.00 degrees. While the B737-800 was even able to fly a 4.50 degree approach, B767-200W and MD-11 could not meet the stabilized approach criteria in this case. However, as the use of spoilers needs to be avoided for noise abatement reasons, the 4.50 degree approach was generally not recommended. It was furthermore concluded that the steeper approach requires a high situational awareness of the pilot when flown for the first time. Additional pilot training would therefore be mandatory in order to integrate the Steep Segmented Approach in line operations.

2.3. Noise Impact Simulation

In order to estimate the noise impact of steeper approaches for EDDK, simulations with the Integrated Noise Model (INM) were performed. The INM is a software using algorithms with noise-power-distance data (FAA 2017). The simulations were initialized for an MD-11 with PW4460 engines and at the angles of 3.0°, 3.5° and 4.0°. Moreover, an aircraft landing weight of 460,000 lbs and ISA standard weather conditions were used as input parameters.

The results of the simulations are shown in Table 1. The greatest impact on the mean noise level seems to be the range between 60 and 70 dB. In the noise segment between 60 and 65 dB, the noise level is reduced by about 25% comparing a 3.0° and a 4.0° approach angle. For noise levels above 70 dB, the simulation did not show significant changes concerning the variation of the approach angle.

The results of the INM simulation identify potential for noise reduction especially in the more distant regions of the airport, where the steeper approach angle leads to a higher vertical distance to the ground. In the area close to the runway, the noise levels are higher and the influence of the steep approach angle is declining, as the final approach path is equal to a conventional approach. This explains why the effect for noise levels above 70 dB is declining.
Table 1: Changes in affected area (reference 3.00°)

<table>
<thead>
<tr>
<th>Noise Level LA max [dB]</th>
<th>3.50° approach [%]</th>
<th>4.00° approach [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>-14.6</td>
<td>-24.8</td>
</tr>
<tr>
<td>65</td>
<td>-15.2</td>
<td>-25.4</td>
</tr>
<tr>
<td>70</td>
<td>-8.9</td>
<td>-6.6</td>
</tr>
<tr>
<td>75</td>
<td>-0.8</td>
<td>-1.0</td>
</tr>
<tr>
<td>80</td>
<td>0.3</td>
<td>0.2</td>
</tr>
<tr>
<td>85</td>
<td>0.5</td>
<td>0.4</td>
</tr>
<tr>
<td>90</td>
<td>+0.3</td>
<td>+0.6</td>
</tr>
</tbody>
</table>

The noise simulations show potential of the Steep Segmented Approach for a noise reduction at EDDK. Due to limitations of the INM simulation, such as the flap settings of the MD-11 or the deployment of the gear, the results do not replace but form a good theoretical basis for real test flights.

3. TEST FLIGHTS

After simulating both the conduct of Steep Segmented Approach in a flight simulator as well as the noise impact of the Steep Segmented Approach with the INM, real test flights were performed in September 2016 at EDDK. The main objective for the test flights was the validation of the simulated results. At the same time, the situational awareness and work load for a pilot can only be assessed under real life conditions.

3.1. Testing Scenario

Between September 15th and September 25th, both UPS Airlines and TUIfly performed a total of nine Steep Segmented Approaches. While UPS Airlines used a B767-300W for separately scheduled research flights with go around, TUIfly used a B737-800 and integrated the test flights into ordinary line operations. The TUIfly test flights were operated in the name of Air Berlin and therefore have flight numbers from Air Berlin. As just stated, the conditions for the test flights of both airlines were quite different. Since the trials performed by TUIfly meet the conditions of daily airport business more closely, in the following, the four TUIfly test flights are going to be described and analyzed.

Originally, 22 test flights had been planned, but due to the use of Runway 14L and adverse weather conditions, only four flights could be realized. The test flights consisted of a steep 3.5° segment and an ordinary 3.0° segment. They were flown by different flight crews. An exemplary flight profile including altitude and flap settings of TUIfly Test Flight #1 is shown in Figure 2.

The graph of the altitude starts with the intermediate approach until 10,000 ft MSL. The steeper segment starts at 10,000 ft MSL in a 3.5° angle. At an altitude of 2000 ft MSL, slope changes to a 3.0° angle, which continues until the threshold. The flapsetting resembles a staircase shaped pattern. Until the switch between the 3.5° and the 3.0° segment at 2000 ft MSL, the aircraft is flown in clean configuration. At 2000 ft MSL, flaps are extended in two steps. The retraction of the flaps is performed after the threshold.
3.2. Results

For the measurement of the noise output, there were four noise sensors along the final approach trajectory to Runway 32R in Cologne Bonn Airport. The location of the noise sensors and the flight trajectory of the Test Flights #1, #2 and #3 can be seen in Figure 3. The most distant noise sensor is “Messfahrzeug Buchholz” with 12 NM distance to the threshold. The noise sensors in Hennef, Siegburg and Lohmar keep a distance from 2.49 to 6.28 NM to the runway threshold and follow already the 3,0° segment. In the subsequent analysis of the measured data, each noise sensor is evaluated individually.

![Figure 3: Location of noise sensors and flight trajectory of TUIfly test flights](image)

The noise signature of the test flights at the most distant noise sensor, which is “Messfahrzeug Buchholz”, and the average noise signature of the 73X fleet are shown in Figure 4. At the noise sensor “Bucholz”, the vertical derivation between the conventional 3,0° and the steeper 3,5° approach path is approximately 250 ft.

For Flight #4, no noise signature was recorded. For the other three test flights noise signatures between 62,7 and 63,0 dB(A) were measured. The average noise signature of the test flights is 62,8 dB(A), which is 1 dB(A) less than the average noise signature of the 73X fleet. The simulated results from INM are confirmed by these results. However, based on a limited sample, it was considered difficult to draw a reliable conclusion from a statistical point of view.
The second noise sensor “Hennef” has a distance of 6.28 NM to the runway threshold. At this point of the approach, the distance to DKS01, where the final approach path in a 3.0° angle starts, is about 1 NM. Consequently, the vertical derivation between the conventional and the steeper approach is negligible. The noise signatures of the test flights at “Hennef” are shown in Figure 5. While the noise signatures at “Buchholz” varied in a range of 0.3 dB(A), at “Hennef”, noise signatures between 67.2 and 69.9 dB(A) were measured, which leads to a larger range of 2.7 dB(A). With a mean value of 68.5 dB(A), the noise signatures of the test flights are on average 0.9 dB (A) lower than the noise signature of the average 73X fleet. Three out of four test flights had a lower noise level compared to the average 73X fleet.

The last two noise sensors are “Siegburg”, which is located 3.73 NM from the threshold, and “Lohmar”, which is located 2.49 NM from the runway threshold. Both sensors are established on the 3-degree ILS glideslope, so no vertical derivations between the conventional and the steeper approach are expected. The noise sensor “Siegburg” is located right below the final approach track. The noise sensor “Lohmar” is laterally displaced under the approach track. It is, in fact, offset approximately .36 NM to the right of the final approach in a more populated area.

Figure 6 shows the measured noise signatures at “Siegburg” for the test flights and the average 73X fleet. The noise levels show the largest range of 3.2 dB(A) between 74.9 and 78.1 dB(A). With the value of 76.1 dB(A), the mean noise signature is 0.9 dB(A) higher than the noise signature of the average 73X fleet. Three out of four test flights had a higher noise level compared to the average 73X fleet.
The noise signatures of the test flights and the average 73X fleet at the noise sensor “Lohmar” are shown in Figure 7. For the Test Flight #1, no noise signature was recorded. All approaches crossed this sensor at approximately 1,000 ft above ground level and established on the ILS glideslope. The measured noise signatures vary between 65.3 and 66.6 dB(A). The mean value is 65.8 dB and therefore 0.4 dB(A) higher than the noise signature for the average 73X fleet.

4. DISCUSSION AND OUTLOOK

In this paper, the theoretical framework for the implementation of test flights in a Steep Segmentend Approach is presented. Therefore, the procedure design and the results of simulator trials with B767, MD-11 and 737-800 are included. Within the flyability study, all aircraft were found capable of flying a dual segment approach with a steep first segment of 4.0° degree. Moreover, noise simulations with the INM showed potential for a reduction of the noise signature for noise levels between 60 and 70 dB.

Finally, the scenario and the results of test flights conducted at EDDK by TUIfly are presented. The noise measurements of the test flights show a small decrease at the most distant noise sensor (~1 dB). For the other noise sensors, no general conclusion could be drawn. In fact, those noise sensors are either very close or actually on the final approach path on the 3.0° ILS glidepath. As the flights were operated by different crews, it is difficult to compare these flights on a configuration level. Moreover, the number of test flights is not sufficient to draw conclusions on a statistical level.

One possibility to further investigate the Steep Segmented Approach would be the use of a pilot assistance system for noise-optimized approaches. By doing so, the individual influence and decisions of a flight crew would be eliminated as an interfering factor for reproducible approaches.
5. REFERENCES

EUROCONTROL, Analysis of vertical flight efficiency during climb and descent. Technical report, 2017

