OAS Surface Optimization of Shuangliu Airport based on Collision Probability Calculation

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Abstract. Airport clearance safety management is an important part of airport operation indicators. Controlling obstacle height is one of the most important tasks in airport clearance management. The current program design and evaluation in China currently uses the obstacle restriction surface (ILS) and Obstacle Evaluation Surface (OAS). The current program design in our country rarely uses the collision risk mode (CRM), but the obstacles around the airport are gradually increasing. At this stage, the OAS surface is more conservative. A simplified model with a collision probability of approximately 1x10^-7 is constructed and compared with the OAS surface to improve it. The results show that the slope of the original OAS surface is larger than that of the simplified model. The improved OAS surface meets the target safety level and solves the problem of being too conservative.

1. Introduction
The airport clearance zone is an important barrier to ensure the safety of aircraft taking off and landing[1]. In the precision approach stage, obstacles need to be restricted in height. At this stage, the OAS surface is too conservative and the airspace utilization rate is low. It will not only increase the cost when constructing the airport, but also restrict obstacles. Therefore, the current OAS needs to be restricted. To conduct research.

In China, Luo studied the assessment of airport clearance obstacles based on Geographic Information System (GIS)[2]. There are also many domestic collision studies on the approach phase, such as the collision risk model study of the aircraft approach and landing phase of Ye Youjun et al[3]. However, the current domestic program design does not use the CRM mode[4], so there are not many experimental results using the CRM mode to optimize the OAS surface. At present, Feng Kuikui and others use the obstacle elliptical evaluation surface of CRM to optimize the OAS surface[5], but The oval model is not intuitive enough for comparison and improvement.

There is also a certain amount of domestic research on the collision of Shuangliu Airport. Based on the environment of Shuangliu Airport, Zhang Zhiwei and others used the collision risk model to analyze and study the safety problem of increasing the airport capacity under the independent parallel approach mode[6]. Li Jie et al. took the main aircraft operating at Shuangliu Airport as the research object, and under the condition of focusing on the impact of wakes, taking into account the pilot's operating error, simulation research on the collision probability and dangerous approach probability in three directions[7].

Because the principle of OAS setting is that the probability of collision between aircraft and obstacles is a 1x10^-7 equal probability plane tangent plane, this paper simplifies CRM to a simplified model of the tangent plane, and compares this model with the OAS surface and improves it. Find the characteristic value in the section to simulate the obstacle to calculate the collision probability.
2. Simplified Model of Collision Hazard Mode

2.1. OAS Surface

**OAS Constant**

The A, B, and C constants on the OAS surface can be found in the OAS constant table in the appendix of ICAO Document 8168. These schedules respectively list the OAS constants and template coordinates of various ILS approaches under standard conditions of 2.5~3.5 and LLZ/THR of 2000~4500m based on the combination of the heading station-to-entry distance (LLZ/THR) and glide angle. The Shuangliu Airport was selected for the test, and ILS approach. The main design parameters are a go-around climb gradient of 2.5%, a down angle of 3°, and a go-around ascent gradient of 2.5%.

|          | W side   | X side   | Y side   | Z side   |
|----------|----------|----------|----------|----------|
| A        | 0.028500 | 0.027681 | 0.023948 | -0.025000|
| B        | 0.000000 | 0.182500 | 0.210054 | 0.000000 |
| C        | -8.01    | -16.72   | -21.51   | -22.50   |

\[
W \text{ Noodles: } z = 0.0285x - 8.01
\]

\[
Y \text{ Noodles: } z = 0.023948x + 0.210054y - 21.51
\]

\[
X \text{ Noodles: } z = 0.02782x + 0.1825y - 16.72
\]

\[
Z \text{ Noodles: } z = -0.025x - 22.5
\]

2.2. CRM Ellipse Evaluation Surface Establishment

According to the current regulations, the description of the CRM equiprobability line: the equiprobability line at any cross section can be described by elliptical lines[8]. At present, there have been researches on the elliptical evaluation surface composed of obstacles and aircraft collision probability of 1x10^-7[9]. The CRM ellipse evaluation surface formula at 7800 meters from the runway entrance is

\[
\frac{(y'-1)^2}{507.7^2} + \frac{(z-425.0)^2}{194.6^2} = 1
\]

Where \(y'\) and \(z\) are the horizontal and vertical positions. The center of the ellipse is the intercept point of the nominal track at that point O(7800,0,425).

The point selection for the constructed elliptical evaluation surface is simplified to a tangent plane similar to OAS, and the flight path deviation calculation and construction model are used. Therefore, when the simplified evaluation surface is constructed, the aircraft deviation method is also used to select points, that is, it is necessary the standard deviation of the aircraft's position. The value of the standard deviation of each position has been explained in the DOC9274 document, and the value of the type I approach is shown in Table 2.

| Instrument landing type | Range (m) | Horizontal distribution | Vertical distribution |
|-------------------------|-----------|------------------------|----------------------|
| CAT I                   | 1200      | 16.4                   | 5.8                  |
| CAT I                   | 4200      | 35.9                   | 13.6                 |
| CAT I                   | 7800      | 67.5                   | 27.4                 |

Find a point H outside the equal probability ellipse by the multiple of the lateral standard deviation
method, use the ellipse formula and the OAS surface feature to construct a simplified section as shown in Figure 2. In the figure, H1 and H2 are flush and symmetrical with the center of the ellipse, extending H1 and H2 is tangent to the ellipse and is connected to the tangent line of the ellipse vertex b to intersect at F1 and F2.

Figure 1. Schematic diagram of simplified section

3. Collision Probability Calculation

The precision approach collision risk model is a computerized model developed in the 1970s to estimate the probability of collision with obstacles during a precision approach. The collision risk model uses the runway coordinate reference system (at the starting point) to define the position of the aircraft and obstacles. The probability distribution of the independent horizontal and vertical expansion of the aircraft on the nominal path is \( [g_{xy}, h_{xz}] \), and the horizontal coordinate is \( y_{k1} \) to \( y_{k2} \) and the height is \( z_{k} \). The probability of collision with the obstacle of \( z_{k} \) can be calculated as

\[
P(O_K) = \int_{y_{k1}}^{y_{k2}} g_x(y) dy \int_{0}^{z_k} h_x(z) dz
\]  

\( g_x(y) \) is the probability density function of lateral deviation, \( h_x(z) \) is the vertical deviation probability density function. \( \int_{y_{k1}}^{y_{k2}} g_x(y) dy \) indicates the probability that the aircraft and the obstacle overlap laterally; \( \int_{0}^{z_k} h_x(z) dz \) indicates the probability that the aircraft and the obstacle overlap vertically.

H1 and H2 take three eigenvalues, the y value of the first group H1 and H2 is 17 times the lateral standard deviation of x at 7800 meters; the y value of the second group H1 and H2 is the side of x at 7800 meters 11.6 times the lateral standard deviation; the y value of the third group H1 and H2 is 6.2 times the lateral standard deviation when x is 7800 meters, that is, it is just taken on the ellipse evaluation surface, combined with the ellipse formula and the characteristics of the OAS surface, we get the other coordinates of the midpoint of the same section are shown in Table 3.

| Number of groups   | H1     | H2     | F1     | F2     | K    |
|--------------------|--------|--------|--------|--------|------|
| The First group    | (1147.5, 425) | (-1147.5, 425) | (126, 231) | (-126, 231) | 0.19 |
| The Second Group   | (783, 425) | (-783, 425) | (178, 231) | (-178, 231) | 0.32 |
| The third group    | (418.5, 425) | (-418.5, 425) | (267, 231) | (-267, 231) | 1.28 |

Compare the three newly created OAS surfaces with the original OAS surfaces at the same section, as shown in Figure 2.
In the selected OAS surface, the selected points H1, F1, and Z1 on the OAS surface are simulated obstacles and the collision probability is calculated. The obstacle width is assumed to be 50m. Standard deviation of the horizontal and vertical distribution of track deviation: $\sigma_{lat}(x')$ is 67.5m, $\sigma_{ver}(x')$ is 27.4m. The mean value of the lateral and vertical deviation distribution is 0.40. The calculation process and results are shown in Table 4.

The collision risk probability of obstacles in the calculation example is much smaller than $1.0 \times 10^{-7}$. So the three hypothetical obstacles H1, F1, Z1 will not affect the aircraft's precision approach and landing.

The result shows that the original OAS surface is too conservative, and the optimized OAS surface has looser restrictions than the original OAS surface, so it is necessary to improve the OAS surface. When the value of H1 is 17 times the lateral standard deviation, the OAS surface is not much different from the original OAS surface, and the surrounding obstacles are similar to the original OAS surface, and each point on its OAS surface The collision probability is much smaller than $1x10^{-7}$, and for H1 when the value of x is 7800 meters, the lateral distance is 6.2 times the lateral standard deviation, but the improved OAS-W faces the surrounding obstacles too much. , It is counterproductive. Therefore, the most suitable choice is that the H1 distance is 11.6 times the lateral standard deviation. At this time, the collision probability of the points on the OAS-X surface is less than $1x10^{-7}$, and the OAS-X
surface is not too limited.

4. Conclusion
According to the above model establishment and calculation analysis, it can be seen that the simplified OAS cross-section model is more intuitive when compared and optimized with the original OAS surface, and it is more convenient to choose the best solution. After comparison, it is found that the original OAS surface is too conservative, but after the comparison of the three sets of simplified models, it is found that the OAS-X slope cannot blindly choose the largest value to reduce the overall limit of the OAS surface, because at this time, although the side limit is reduced, it will increase the limit of the OAS-W surface, so it is necessary to ensure that the probability of collision between the aircraft and the obstacle is less than $1 \times 10^{-7}$, the slope of OAS-X is slightly increased, and the width expansion rate of OAS-W is slightly increased, so that the obstacle restriction area on the side of the OAS facing the precision approach runway is lowered.

5. References
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