International Civil Aviation Organization

WORKING PAPER

A41-WP/482
TE/174
30/8/22
(Information paper)
English and Chinese only[1]

ASSEMBLY — 41ST SESSION

TECHNICAL COMMISSION

Agenda Item 31: Aviation Safety and Air Navigation Standardization

RESEARCH ON AND APPLICATION OF THE RECAT WAKE

(Presented by China)

EXECUTIVE SUMMARY

The wake turbulence separation criteria proposed more than fifty years ago in the *Procedures for Air Navigation Services — Air Traffic Management* (PANS-ATM, Doc 4444) ensures safety but also limits the increase in airport capacity. This report analyzes the current RECAT separation criteria in Europe and the United States, introduces the research on and application of the RECAT in China, and then proposes recommendations on the RECAT wake turbulence separation criteria and statistical parameters for RECAT test operation. It is recommended that the Assembly discuss this issue.

Strategic Objectives:	None
Financial implications:	None
References:	Doc 4444, *Procedures for Air Navigation Services — Air Traffic Management* (PANS-ATM) ICAO SASP-WG/29-WP/28, Runway Spacing Required for Segregated Parallel Approaches/Departures, May 2017.

[1] English and Chinese versions provided by China.

1. INTRODUCTION

1.1 Wake turbulence separation criteria proposed more than 50 years ago in ICAO Doc 4444 divided aircraft into three categories according to the maximum take-off weight and provided the wake turbulence separation criteria for aircraft under different category combinations. When the A380 was put into service, the new separation criteria were supplemented by the ICAO State Letter on update guidance for wake turbulence aspects of Airbus A380-800 aircraft, but Doc 4444 was not revised accordingly. Different aircraft in the same category vary greatly in weight, wingspan and speed, and the safety margins are also different, which makes it possible to reduce the wake turbulence separation. As air traffic flow continues to grow, the wake turbulence separation criteria based on practice has limited the increase in airport capacity to some extent, causing unnecessary flight delays. In the section of Airport Operational Threads in the Aviation System Block Upgrade Plan (ASBU) published by ICAO, three wake turbulence separation upgrade modules are given. The first of these modules is the RECAT.

1.2 The Civil Aviation Administration of China (CAAC) issued the ASBU Development and Implementation Strategy for China Civil Aviation in 2015. This document introduced all the requirements in the module of wake turbulence separation thread in ASBU Performance Improvement Area 1 (Airport Operations).In 2015, the Air Traffic Management Bureau (ATMB) of CAAC and the Civil Aviation University of China (CAUC) cooperated in the project of Feasibility Study and Validation of Technology for Reducing Wake Turbulence Separation Based on Aircraft Recategorization (RECAT) to study the feasibility, implementation conditions and recommended program for promoting the application of the RECAT in China. In December 2019, the China civil aviation started to implement the RECAT-CN test operation in Guangzhou Baiyun Airport and Shenzhen Baoan Airport. In December 2020, the RECAT-CN test operation was implemented at 12 major airports in China, including Beijing Capital Airport and Shanghai Hongqiao Airport.

2. DISCUSSION

2.1 RECAT-CN Program

2.1.1 Aircraft RECAT

2.1.1.1 As the number of light aircraft at Chinese airports that need implementation of the RECAT operation is relatively small in general, for the sake of safety, it is recommended that only heavy aircraft be divided into Categories B and C. The other categories of aircraft are the same as those of the ICAO Doc. 4444. In the RECAT-CN, aircraft are divided into the following five categories according to the maximum allowable gross takeoff weight and wingspan of the aircraft:

1. Super heavy aircraft (Super): aircraft whose maximum allowable gross take-off weight is or greater than 136,000 kg, and whose wingspan is or greater than 75 meters, and whose wake turbulence category identifier is J.

2. Heavy aircraft (Heavy): aircraft whose maximum allowable gross take-off weight is or greater than 136,000 kg, whose wingspan is or greater than 54 meters but less than 75 meters, and whose wake turbulence category identifier is B.

3. General heavy aircraft (Heavy): aircraft whose maximum allowable gross take-off weight is or greater than 136,000 kg and whose wingspan is less than 54 meters, and whose wake turbulence category identifier is C.

4. Medium aircraft (Medium): aircraft whose maximum allowable gross take-off weight is greater than 7,000 kg and less than 136,000 kg, and whose wake turbulence category identifier is M.

5. Light aircraft (Light): aircraft whose maximum allowable gross take-off weight is or less than 7,000 kg, and whose wake turbulence category identifier is L.

2.1.1.2 Among them, B757 aircraft (including B757-200, B757-300, etc.) belong to Medium aircraft.

2.1.2 Aircraft Wake Turbulence RECAT Control (Radar) Wake Turbulence Separation Criteria

2.1.2.1 For aircraft pair that take off or approach successively, the radar wake turbulence separation criteria shall be in accordance with the following provisions:

1. When the leading aircraft is a super heavy aircraft (J) and the following aircraft is a heavy aircraft (B), the separation shall not be less than 9.3 kilometers.

2. When the leading aircraft is a super heavy aircraft (J) and the following aircraft is a general heavy aircraft (C), the separation shall not be less than 11.1 kilometers.

3. When the leading aircraft is a super heavy aircraft (J) and the following aircraft is a medium aircraft (M), the separation shall not be less than 13.0 kilometers.

4. When the leading aircraft is a super heavy aircraft (J) and the following aircraft is a light aircraft (L), the separation shall not be less than 14.8 kilometers.

5. When the leading aircraft is a heavy aircraft (B) and the following aircraft is a heavy aircraft (B), the separation shall not be less than 5.6 kilometers.

6. When the leading aircraft is a heavy aircraft (B) and the following aircraft is a general heavy aircraft (C), the separation shall not be less than 7.4 kilometers.

7. When the leading aircraft is a heavy aircraft (B) and the following aircraft is a medium aircraft (M), the separation shall not be less than 9.3 kilometers.

8. When the leading aircraft is a heavy aircraft (B) and the following aircraft is a light aircraft (L), the separation shall not be less than 13.0 kilometers.

9. When the leading aircraft is a general heavy aircraft (C) and the following aircraft is a medium aircraft (M), the separation shall not be less than 6.5 kilometers.

10. When the leading aircraft is a general heavy aircraft (C) and the following aircraft is a light aircraft (L), the separation shall not be less than 11.1 kilometers.

11. When the leading aircraft is a medium aircraft (M) and the following aircraft is a light aircraft (L), the separation shall not be less than 9.3 kilometers.

2.2 Implementation of the RECAT-CN

2.2.1 On December 5, 2019, China civil aviation started the RECAT-CN test operation in Guangzhou and Shenzhen. Before the implementation, China civil aviation completed the RECAT-CN safety assessment, upgrading of label display of air traffic management automation system, upgrading of electronic flight strips, test operation plans, theoretical training for controllers, controller training based on control simulators, training and publicity for airlines and revision of AIC.

2.2.2 The additional cost required to implement the RECAT-CN is little, including the cost in the upgrading of wake turbulence identification and personnel training in the ATC automation system. Airlines do not need to change the aircraft categories in the ICAO flight plan.

2.2.3 On the basis of the first phase of test operation, from December 31, 2020, the RECAT-CN has been further implemented at 12 major hub airports such as Beijing Capital Airport and Shanghai Hongqiao Airport. The statistics of the actual operation data show that the wake turbulence separation can be reduced by a maximum of 23%, and the average capacity increase is about 2%. Compared with the current RECAT criteria in Europe and the United States, the RECAT-CN is more adapted to traffic flow at airports in China and thus is easier to operate and implement.

2.3 Statistical Analysis of the Effect of the RECAT-CN Test Operation

2.3.1 According to the RECAT-CN separation criteria, the category combinations that can reduce the separation after implementing the RECAT-CN include JB, BB, CB, CC, CM, etc. When the leading aircraft is B757 (B752, B753), the wake turbulence separation with the following aircraft is no longer determined by the heavy aircraft, but by the medium aircraft (at this time, when the following aircraft is of Categories B, C or M, separation can be reduced). According to the "flight pair" data collected by radar records, the following technical indicators are defined to reflect the effect of implementing the RECAT-CN.

1) Number of flights that meet the requirements of category combination (*N*): within the statistical time cycle, the number of flights that meet the requirements of the pair category combinations (i.e. JB, BB, CB, CC, CM), or the leading aircraft is B757 aircraft;

2) The number of flights that have implemented the RECAT-CN (N_{RECAT}): within the statistical time cycle, the following requirements are met: (a) the pair category combinations (i.e. JB, BB, CB, CC, CM) or the leading aircraft is a B757 aircraft ; (b) The following aircraft is the experimental subject; (c) The actual separation between the leading aircraft that is landing and the following aircraft is less than 1.5 times as much as the required separation(the RECAT-CN);

3) Percentage of the number of the flights that have implemented the RECAT-CN (P_{RECAT}): The percentage of the number of flights that have implemented the RECAT-CN in the number of flights that meet the category combinations, which is:

$$P_{\text{RECAT}} = \frac{N_{\text{RECAT}}}{N} \quad (1)$$

4) The number of flights that implement the RECAT-CN precisely($N_{\text{precision}}$): when the leading aircraft enters the runway and lands, the actual separation with the following aircraft is less than 1.3 times as much as the required separation (the RECAT-CN);

5) Accurate implementation rate of the RECAT-CN ($P_{\text{precision}}$): The ratio of the number of flights that accurately implement the RECAT-CN to the number of flights that have implemented the RECAT-CN, which is:

$$P_{\text{precision}} = \frac{N_{\text{precision}}}{N_{\text{RECAT}}} \quad (2)$$

6) The reduced separation rate of the RECAT-CN ($P_{\text{ReducedSeparation}}$): For each flight pair that has implemented the RECAT-CN operation, divide the difference between the current separation and the RECAT-CN separation by the current separation to obtain the reduced separation rate, and then calculate the separation reduction rates for all pairs of flights that have implemented the RECAT-CN operation, and average them, which is:

$$P_{\text{ReducedSeparation}} = \frac{\sum_{i=1}^{N_{\text{RECAT}}} \left(\frac{S_{i_{\text{CAAC}}} - S_{i\,\text{RECAT}}}{S_{i_{\text{CAAC}}}} \right)}{N_{\text{RECAT}}} \quad (3)$$

In the formula, i is the serial number of the "flight pair"; $S_{i_{\text{CAAC}}}$ is the current required separation for the "i th" flight pair (that is, the minimum wake turbulence separation specified in CCAR93-R5); $S_{i_{\text{RECAT}}}$ is the RECAT-CN required separation for the "i th" flight pair (that is, the minimum wake turbulence separation specified in the RECAT-CN control test operation plan).

7) The number of flights that RECAT-CN can increase ( ): the reduced separation rate multiplied by the number of flights that have implemented the RECAT-CN, which is:

$$\begin{aligned} \Delta N &= P_{\text{ReducedSeparation}} \times N_{\text{RECAT}} \\ &= P_{\text{ReducedSeparation}} \times P_{\text{RECAT}} \times N \end{aligned} \quad (4)$$

8) Relative RECAT-CN separation ($S_{\text{relativeRECAT}}$): For each flight pair that has implemented the RECAT-CN, divide the required RECAT-CN separation by the actual separation between the leading aircraft that is entering the runway and landing and the following aircraft to obtain the

relative RECAT-CN separation and then calculate the relative RECAT-CN separations for all pairs of flights that have implemented the RECAT-CN operation, and average them, which is:

$$S_{\text{relativeRECAT}} = \frac{\sum_{i=1}^{N_{\text{RECAT}}} \left(\frac{S_{i_{\text{really}}}}{S_{i\ \text{RECAT}}} \right)}{N_{\text{RECAT}}} \quad (5)$$

In the formula, $S_{i_{\text{really}}}$ is the actual separation between the leading aircraft entering the runway and landing and the following aircraft.

9) Relative current separation ($S_{\text{relativeCAAC}}$): The actual separations between the leading aircraft entering the runway and landing and the following aircraft are divided by the required wake turbulence separation specified in CCAR-93-R5 to obtain the relative current separations and then average them. For airlines whose following aircraft implement the RECAT-CN, the formula is as follows:

$$S_{\text{relativeCAAC}} = \frac{\sum_{i=1}^{N_{\text{RECAT}}} \left(\frac{S_{i_{\text{really}}}}{S_{i\ CAAC}} \right)}{N_{\text{RECAT}}} \quad (6)$$

For airlines whose following aircraft have not yet implemented the RECAT-CN, the formula is as follows:

$$S_{\text{relativeCAAC}} = \frac{\sum_{i=1}^{N_1} \left(\frac{S_{i_{\text{really}}}}{S_{i\ CAAC}} \right)}{N_1} \quad (7)$$

Among them, N_1 is the number of flights , when the final separation between leading aircraft and following aircraft is less than 1.5 times as much as the required separation, and also the following flight belong to the airlines who have not implemented RECAT-CN.

10) Relative required separation ($S_{\text{relativeRequirement}}$): the ratio of the actual separation between the leading aircraft that is landing and the following aircraft to the required separation criteria. For flight pairs that have implemented the RECAT-CN, that is, "relative RECAT-CN separation ($S_{\text{relativeRECAT}}$)"; for flight pairs that have not implemented the RECAT-CN, that is, "relative current separation ($S_{\text{relativeCAAC}}$)". This indicator reflects a controller's ability to control separation criteria.

2.3.2 According to the "flight pair" data collected by radar records, and based on the technical indicators in the previous section, the effect of the three-month implementation of the RECAT-CN at an airport is as follows:

Statistical indicators	1st month		2nd month		3rd month	
	Implement	Not implement	Implement	Not implement	Implement	Not implement
Number of flights that meet requirements of the category combination	491	361	388	301	429	313
Number of flights that have implemented the RECAT	229	/	197	/	131	/
Percentage of flights that have implemented the RECAT	46.64%	/	50.77%	/	30.54%	/
Number of flights that accurately implement the RECAT	120	/	110	/	59	/
Percentage of flights that accurately implement the RECAT	52.40%	/	55.84%	/	45.04%	/
Reduced separation rate for the RECAT (average)	21.14%	/	20.90%	/	20.93%	/
Number of flights that the RECAT can increase	48.40	35.58	41.17	31.94	27.42	20.00
Relative RECAT separation (average)	1.2793	/	1.2705	/	1.2958	/
Relative current separation (average)	1.0082	1.2549	1.0038	1.2359	1.0229	1.3069
Relative required separation (average)	1.2793	1.2549	1.2705	1.2359	1.2958	1.3069

2.3.3 The statistical analysis of the indicator of relative current separation shows that the values of the flights implementing the RECAT-CN are significantly lower than those of the flights that haven’t implemented RECAT-CN, indicating that effect of the actual separation reduction is significant. The data show that after the implementation of the RECAT, the separation on the final is reduced by about 20% for the flight pairs that meet the requirements of the pair category combinations.

2.3.4 In the statistical analysis of the indicator of the relative required separation, the controller's skills of applying the separation criteria are examined. The data show that there is no significant difference between the implementation of the RECAT separation and that of the original separation criteria, indicating that the controller is proficient in implementing the RECAT separation criteria.

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