Analysis on variation of wake separation standard at home and abroad

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Abstract

Aircraft wake is one of the important factors affecting airport capacity and flight safety. Reducing the minimum wake safety separation and increasing the number of aircraft take-off and landing will help to alleviate the flow control of large airports and improve the airport operation efficiency. Our country has further reduced the wake safe separation on the basis of the original wakes safety separation standard, which is in line with the current ICAO wakes safe separation standard, which is helpful for our country to carry on the related exchange with other countries in civil aviation wake. The United States FAA and European Control have been perfecting the proposed wake standards and then (RECAT), gradually introduced a new policy to refine the wake safety separation between aircraft. In this paper, the main aircraft in our country are divided and analyzed by RECAT for reference of the foreign research results, and the vortex strength of each aircraft is compared, the latest study on the wakes policy of foreign countries is presented, which provides a reference for the formulation of the wakes policy in our country.

Keywords

Flight safety, Standard for safe separation of wake turbulence, Vortex strength, Wake policy.

1. Foreword

With the increase of the number of flights, the air traffic management is facing severe challenges in the new situation. The program is designed around the problems of reducing the landing and landing separations of aircraft and ensuring the safe and efficient operation of the aircraft. Navigation facilities and regulation management are constantly updated, among which, reducing the minimum wake separation between aircraft is also an important part of further improving efficiency, and domestic and foreign are also actively exploring and updating.

As early as the 36th session of the General Assembly of the International Civil Aviation Organization, the Russian Federation submitted the urgent issue of the safety of civil aviation wake turbulence. Among them, the typical wake related aircraft accidents and accident symptoms are pointed out. Europe and the United States have established the Wake turbulence Coordination Council and actively carried out relevant research. The wake re-classification is the best proof, but for our country, Whether considering the trend of civil aviation development, or from the point of view of safety or economic benefit analysis, the study of wake flow and the promotion of policy are necessary. In order to ensure the flight safety of the aircraft, China has introduced a series of regulations on wake spacing. The minimum standard for wake separation is stipulated in the Air Traffic Management rules of China Civil Aviation in 1990. The regulations on the running of parallel Runway and instrument in 2004 stipulate the running of parallel Runway under the minimum Wake spacing Standard. The minimum Wake spacing Standard for A380 Super large aircraft in 2008 is stipulated in the regulations on Wake Type and Wake spacing of Airbus A380 models in 2008. In the advisory notice of Wake and parallel Runway Operation in 2015, the harm and avoidance methods of wake are pointed out.

As early as 2000, A.Hinton and so on combined with weather and wake characteristics, designed and updated the aircraft wake separation system to increase the airport throughput, and provided guidance and guarantee for the minimum wake spacing safety between aircraft. In 2002, Hu Jun demonstrated the minimum wake spacing standard under radar control conditions in detail [1], and made a comparative analysis and study on several kinds of wake spacing standards implemented in the early stage. Steven Lang et al. [2] analyzed the change of minimum wake safety separation of aircraft under ICAO wake turbulence reclassification, and used wake induced roll torque factor to judge the wake of the aircraft. The usability of the safe separation matrix for wake reclassification is proved. In 2011, Liu Fang [3] pointed out the importance of wake spacing, and discussed the application and reduction of wake spacing. In 2014, Faye Wong et al. [4] analyzed the structure composition and application of wake spacing reduction technology at home and abroad, and pointed out the future development trend of wake spacing distance standard to wake separation time standard. In 2015, Li Yaowei [5]. Nie run Rabbit et al [6] made a comparison and safety assessment of the current wake classification standard (RECAT), which is tested and popularized by FAA. Wei Zhiqiang et al. [7] compared with FAA RECAT1,RECAT1.5 and RECAT-EU, analyzed the operation effect of western countries, and predicted the implementation of RECAT in China. The continuous study of wake provides a reference for the improvement of wakes policy in China.

2. Advance of Wake spacing Standard in China

In order No. 30 of 2017, China revised the wake separations between aircraft. From the contents of the revisions, we can see that the classification of aircraft wake is still divided into three categories according to the maximum allowable take-off full weight of the aircraft. However, the wake spacing between aircraft is basically in line with the current ICAO wake separation standard, and the wake separation between most aircraft is reduced, and the influence of wake on traffic flow is further reduced.

The main civil aircraft in China are classified according to the current wake separation standard. As shown in figure 1, each aircraft is classified into three categories: heavy, medium and light.

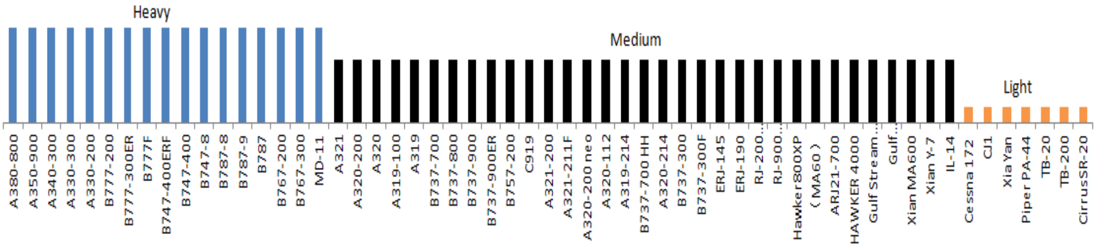

Fig. 1 Wake classification of major civil aircraft in China

Compared with the civil aviation regulations before revision, the radar wake separation standards for different types of aircraft running as shown in Table 1 are obviously reduced, and are basically the same as the current ICAO wake separation standards. B737 and A320 are the most widely used models in our country. It can be seen from the table that they belong to medium-sized aircraft. The wake separation between this type of aircraft and heavy aircraft is 9.3 km, which is 0.7 km less than before. In terms of the number of take-offs and landings of the aircraft per day, The capacity problem can be greatly alleviated.

Table 1 current radar wake spacing standards in China

Aircraft type		Radar wake separation （km）
leader	follower	
A380	Heavy	11.1
	Medium	13.0
	Light	14.8
Heavy	Heavy	7.4
	Medium	9.3
	Light	11.1
Medium	Light	9.3

Taking B747-400 and A320 as examples, according to the new standard of wake spacing in the Civil Aviation Air Traffic Management Code, the maximum take-off amount of B747-400 as shown in figure 2 is 396890 kg, and the maximum take-off weight of the heavy aircraft A320 is 73500kg, which is a medium aircraft. During departure, the minimum wake interval between the B747-400 aircraft and the A320 aircraft was reduced from the original 10km to 9.3 km, and all were safe. This can effectively increase the number of take-offs and landings of the aircraft for busy airports. Improve airport flow control capability.

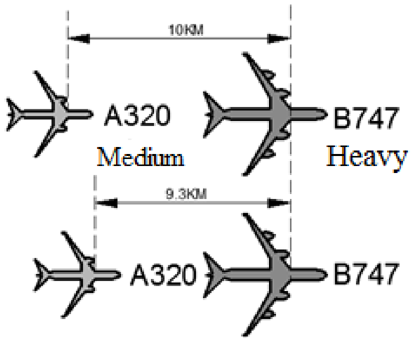

Fig. 2 Wake spacing standard between heavy and medium machines

3. Discussion on reclassification of wake

Both FAA and European control are actively developing the Recategorization of wake, that is, further dividing the types of aircraft wake and further reducing the standard of wake spacing between aircraft on the basis of safety. From the uniform wake spacing of the aircraft type to the one-to-one partition between the aircraft types, the wake spacing standard is more refined and accurate. In addition, with the increase of the short-range parallel runway, the coordinated take-off and landing of the short-range parallel runway is also the focus of domestic and foreign research. Since 2006, the (CSPR) has been studying the safe wake mitigation program for the short-range parallel runway. In 2008, D. Williams et al. [8] evolved an approach wake turbulence to mitigate (WTMA), cross-wind conditions and reduce the wake spacing standard. In 2013, A. Tittsworth J et al. [9] pointed out the FAA 7110.308 rule, which consists of an off-site wake turbulence mitigation (WTMD), WTMA and RECAT as a complete set of wake mitigation schemes to support the realization of the next generation air traffic system (NextGen) goals.

According to Kutta-Joukowski theorem of lift loop, the intensity of wake produced by aircraft is mainly related to the weight, wingspan, and speed of the aircraft, so FAA RECAT1.5 classifies the aircraft according to its maximum take-off weight and wingspan. The aircraft wake class as shown in Table 2.

Table 2 FAA RECAT1.5 type wake classification

Type	MTOW/klb	WS/ft
A	>=300	>=245
B		245>=WS>=175
C		175>=WS>=125
D	300>MTOW>41	125>=WS>=65
E		90>=WS>=65
F	=<41	=<125

For the main civil aircraft in our country, according to the classification of aircraft type wake according to FAA RECAT1.5, At the same time, as shown in figure 2, the main civil aircraft in our country are classified into categories A, B and C,D,E and F. Here, we can see that the large aircraft A380 is classified separately into category A, the heavy aircraft is divided into categories B and C, and the medium-sized aircraft is divided into categories D and E. Light aircraft as Class

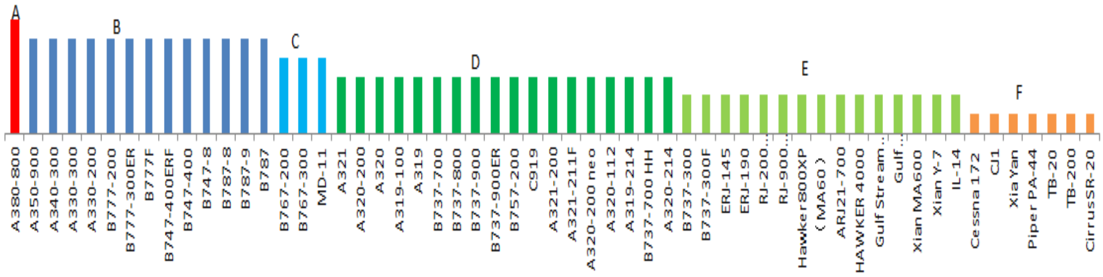

Fig. 3 Classification of main civil aircraft based on FAA RECAT1.5 wake in China

At the same time, the RECAT1.5 also made a detailed minimum wake safety interval based on the ability of the aircraft itself to resist the wake induction, still taking B747-400 and A320 as examples, as shown in figure 3, the wake interval between Class B and Class D aircraft. Compared with the current standards of wake separation in China, the wake safety interval between different types of aircraft is more detailed, from the type of aircraft type to the type of aircraft model and the relative order of each model further development direction.

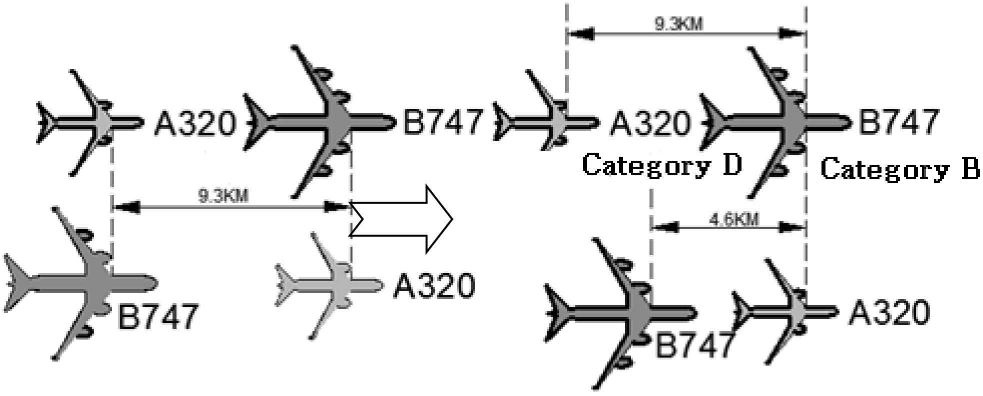

Fig. 4 standard for FAA RECAT1.5 wake spacing between category B and category D aircraft

The influence of wake on the rear aircraft is affected by the intensity of the front wake and the ability of resisting the wake induced by the wake itself. As shown in figure 4, the initial annular volume of the typical civil aircraft in China is much larger than that of the class D aircraft. According to the space-time circulation evolution equation (1) of the decay potential vortex at given viscosity, the variation of wake intensity attenuation as shown in figure 5 can be obtained. The wake flow will drop rapidly after a few seconds, but even if it falls quickly, the intensity of the wake flow will be strong enough for smaller aircraft to seriously affect the normal operation of the aircraft in a short period of time.

$$\Gamma(r,t) = \Gamma_0 \left(1 - \exp(-r^2/4\nu t)\right) \tag{1}$$

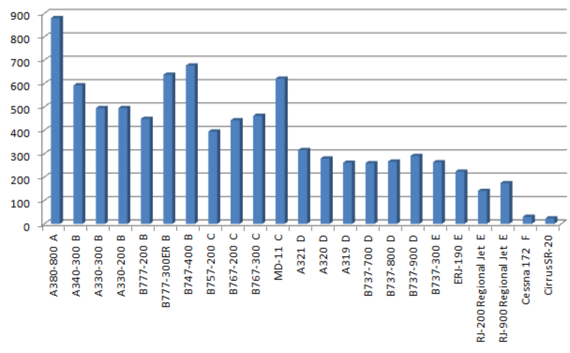

Fig. 5 initial wake intensity of typical models

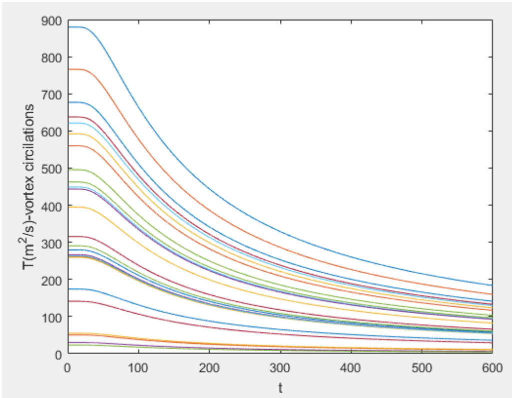

Fig. 6 Wake intensity attenuation

In addition, Han Hongrong et al. [10] establish a calculation model of disturbed parameters, and determine the aircraft safety interval according to the maximum acceptable slope angle of the aircraft. In the research, the aircraft safety interval is usually determined according to the roll angle and the wake vortex induction moment factor.

4. New Development of Wake flow Research

FAA keeps pushing forward in the research of wake flow, and constantly refines the safe interval of aircraft wake. In the command JO 7110.126, the aircraft Integrated Wake Radar interval Standard (CWT),) is continued to describe the pair-wise spacing matrix of the most common type of aircraft identified by ICAO, the development of which depends on the wake data. Instead of weight-based data. On the basis of the classification system established by the command JO 7110.65 on the radar wake turbulence interval, the aircraft grouping is further improved. Divided into category A-A388, category B-Pair-wise Upper Heavy Aircraft, category C- Pair-wise Lower Heavy Aircraft, category D- non-pair-wise heavy aircraft, category E-B757, aircraft, category F-Upper Large Aircraft excluding B757 aircraft, category G-lower large aircraft, category H-Upper Small Aircraft with a maximum takeoff weight of more than 6985 kg up to 18597.3 kg, category I-Small Aircraft with a maximum takeoff weight of 6985 kg or less. At present, small aircraft are defined as aircraft weighing more than 5669.9 to 18597.3 kilograms, a value changed to 6985 kilograms at the lower boundary of a high and small aircraft, which would be consistent with the boundaries of ICAO light and medium aircraft; in addition, You know, there are some small planes in Class I.

The aircraft wake spacing criteria, as shown in Table 3, may be used in the following cases:

(1) when the aircraft in front of the aircraft is flying within 762m from the ground and 305m below the fairway.

(2) when the aircraft in front of the aircraft is flying within 762m from the ground and 152m below the fairway.

(3) close parallel runways which do not involve the departure of Class 2 aircraft before Class E aircraft. Issue wake turbulence warning recommendations and instructions and establish horizontal intervals in accordance with Article 2. No instructions shall be issued to permit the passage of Class I aircraft on Class E aircraft.

Table 3 Wake Turbulence Separation for Directly Behind

		Followers(km)								
		A	B	C	D	E	F	G	H	I
Leade	A		8.33	11.1	12.96	12.96	12.96	12.96	12.96	14.81
	B		5.56	7.41	7.41	9.26	9.26	9.26	9.26	9.26
	C					6.48	6.48	6.48	9.26	9.26
	D		5.56	7.41	7.41	9.26	9.26	9.26	9.26	9.26
	E									7.41

r	F									
s	G									
	H									
	I									

Note: the minimum wake safety interval of the aircraft before and after empty space is 4.63 km.

In the approach process, in addition to the above requirements, in front of the aircraft beyond the landing entrance to ensure the safety of wake as shown in Table 4.

Table 4 Wake Turbulence Separation for On Approach

		Followers (km)								
		A	B	C	D	E	F	G	H	I
Leaders	A		8.33	11.1	11.1	12.96	12.96	12.96	12.96	14.81
	B		5.56	7.41	7.41	9.26	9.26	9.26	9.26	11.1
	C					6.48	6.48	6.48	9.26	11.1
	D		5.56	7.41	7.41	9.26	9.26	9.26	11.1	11.1
	E									7.41
	F									7.41
	G									
	H									
	I									

Note: the minimum wake safety separations of the aircraft before and after empty space is 4.63 km.

Both FAA and Eurocontrol have established their own standards for aircraft wake safety intervals according to their national conditions or geographical characteristics, and are gradually updating their wake standard policies. They are moving from static wake separations standards to dynamic wake separations standards by continuously refining the types of aircraft, while the wake intervals between categories are becoming clearer. Especially in the approach and departure sequence of aircraft in the close parallel runway, a series of measures to mitigate the inlet and outlet wake are implemented, and the aircraft interval is effectively reduced.

5. Conclusion

This paper first introduces the newly modified aircraft wake separation standards in China, classifies the main aircraft running in civil aviation in China, and compares the changes of aircraft wake intervals under the new and old standards. Then we try to classify the main aircraft of our country by FAA RECAT1.5, and determine the safety interval of wake flow according to the order of the aircraft before and after, so as to reduce the departure interval between the aircraft and increase the throughput of the airport. In addition, the formulation of foreign aircraft integrated wake radar interval standard is also discussed, which is based on the measured wake data.

FAA and Eurocontrol make the standard of wake interval according to the local conditions. Under the new situation of the great development of civil aviation, China should adjust the type and quantity of aircraft in operation step by step, study the characteristics of wake, and constantly update the relevant policies and regulations.

Acknowledgements

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