

Multi-airport approach operation mode in Beijing terminal area

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Abstract: With the rapid development of China's civil aviation transportation industry, the air traffic flow is constantly increasing, and the capacity of some busy airports is approaching saturation, which leads to the imbalance of airport capacity and flow, flight delays and other problems. Increasing the number of runways in airports and building new airports are the main means to alleviate the capacity demand. More and more airports in China have started or have increased the number of runways to solve the above problems. Due to the limited airport area and investment cost, compared with the long-distance parallel runways, in most cases, they will choose to build short-distance parallel runways. The near parallel runway (CSPR) has the characteristics of less construction land and higher capacity than a single runway. Pairing is an operation mode to improve the capacity of close parallel runway. However, due to the lag of domestic related research and regulations/standards, CSPR capacity is not significantly increased compared with single runway, which affects the airport transportation capacity. At present, only the isolated parallel running mode is used for the short-distance parallel runway in China. Although this running mode keeps a large safety margin, it reduces the capacity of the runway. Therefore, it is urgent to study the running mode that can improve the capacity of the short-distance parallel runway.

1. Introduction

Today, with the accelerating level of global economy, the development of various fields is showing a thriving scene. This includes the continuous expansion and deepening of aviation business [1]. As an important infrastructure in the field of airport air transportation and cities, it has become the first choice of more and more travelers [2]. The air traffic keeps increasing steadily. Because of its continuous increase, airports with limited capacity need to undertake more flight tasks, which gradually leads to problems such as unbalanced airport capacity and low operating efficiency, and the problem of flight delays is becoming more and more serious [3]. The continuous construction and expansion of civil aviation airports must fully consider the reality of limited land resources [4]. In this severe situation, new or expanded airports must seek ways to save land and make airport operation meet the demand [5]. As far as airport operation is concerned, it is imperative to improve the airport capacity and ensure the throughput demand of the airport. As the runway is the key link in the airport, the capacity of the runway often determines the capacity level of an airport. There are two ways to improve airport capacity: 1. On the premise of limited land resources, improve the traditional runway configuration, select the runway configuration with higher land utilization rate, and increase the number of runways that can be effectively used, so as to improve airport take-off and landing capacity [6]. 2. On the premise of the same runway type, improve the aircraft operation mode, and improve the use efficiency of the runway through a more efficient approach and departure operation method, thus increasing the capacity [7]. Compared with single runway, the capacity of near-distance parallel runway is greatly increased, and the use strategy is more flexible. Compared with long-distance parallel runway, the area and investment cost are less. Therefore, the airport prefers near-distance parallel runway when planning runway.

2. Pairing mode of close parallel runway

2.1. Operation procedure of pairing approach

The initial stage is mainly to select the aircraft that can be paired smoothly, and the flight flow control center plays a major role in this stage. Every day, the take-off and landing flight information of major airport airlines in China will be collected to the flight flow monitoring center in time [8]. Generally speaking, the approach procedure starts from the initial approach positioning point (IAF) until the landing can be completed, including the go-around procedure of the wrong approach. It can be divided into: initial approach segment, intermediate approach segment, final approach segment and go-around segment. The monitoring center will make a reasonable pairing according to the selected destination airport, aircraft type and expected landing time of the aircraft. Usually, two aircraft with a landing time interval of less than 5min before and after the aircraft will be selected for pairing evaluation [9]. The qualified aircraft will be informed by ATC of its position in the paired approach and an arrival time limit "required time", that is, the latest arrival time of the aircraft determined to implement the paired approach at the final approach position point. Among them, the initial approach leg starts from IAF and ends at the intermediate approach anchor point (IF) or the final approach anchor point/final approach point (FAF/FAP), which is mainly used for the descending altitude of the aircraft, and completes the alignment with the intermediate or final approach leg [10].

The instructed pilot should judge the required time, confirm the pairing if it is determined that he can arrive before this time, and fly normally to the vicinity of the final approach positioning point according to the plan to prepare for the pairing [11]. If you can't reach it, report it to the air traffic control department, cancel the operation of the paired approach, and then descend normally according to the conventional standard [12]. The intermediate approach segment is the segment between IF and FAF/FAP, which is mainly used to adjust the shape, speed and position of the aircraft, and descend a little to complete the alignment with the final approach track. The last approach segment is the segment that completes the landing. The part of instrument flight is from FAF to MAP, and the part of visual flight can make a straight line to the airport runway for landing or make a visual hovering approach to the airport.

2.2. Paired departure procedure

According to Order No.123, under the current close-range parallel runway operation mode, two departing aircraft on different runways need to meet the requirement of single runway wake time interval, which is generally 2-3 minutes. In this time interval, the number of planes released per hour is limited, which is a real problem for most busy airports to improve departure capacity. Generally speaking, the departure procedure takes the departure end (DER) of the take-off runway as the starting point, that is, the end of the take-off area (runway end or clearance end). With the in-depth study of aircraft departure process and wake movement for many years, the departure mode of approaching parallel runway can also be adjusted like the paired approach mode, so that the flight time interval between two aircraft on different runways can be reduced, and the rear aircraft can be before the wake of the front aircraft in the whole takeoff stage, thus greatly increasing the departure capacity of approaching parallel runway on the premise of ensuring the safety of aircraft. The departure procedure ends with 3.3% or the gradient according to the requirements of safety over obstacle along the take-off path to the minimum altitude approved in the next flight phase. For the pairing departure procedure, the starting point of the procedure should be the takeoff and taxiing of the pairing front machine.

Compared with the paired approach mode, the paired departure mode has both similarities and differences: in common, the operation principle of paired departure is that the position of the paired rear aircraft is always in the safety zone of the front aircraft collision risk boundary and the rear wake boundary during the whole paired operation stage to ensure the safety of the rear aircraft. The difference lies in that the departure interval standard is the release time interval rather than the distance interval, which provides great convenience for the control of the position interval between

the front and rear machines. When the departure procedures of the paired front aircraft or rear aircraft are finished, or when the paired departure aircraft makes the operation of terminating the paired flight, it can be defined that the paired departure procedures are finished. According to the analysis of the known data of different aircraft types, such as take-off speed, take-off taxiing distance, front wheel lifting time, etc., we can specify a complete set of standards for the initial flight time interval of pairing departure, without considering the influence of many uncertain factors on the whole pairing operation like the pairing approach. In practice, as long as possible, the departure track should be consistent with the runway centerline or its extension line.

3. Runway capacity model in pairing mode

3.1. The runway is only used for the capacity model of landing.

In actual operation, when the aircraft enter the pairing stage, the longitudinal spacing between the aircraft is constantly controlled by the pilot, so that the rear aircraft is always in the safe area. Therefore, in such a high-intensity operating environment, the evaluation of capacity can't all be calculated according to the minimum value of the interval, and the random error in time generated by the pilot must be taken into account. Runway is running in three situations: only for aircraft landing; Only for aircraft take-off; Used for aircraft landing and take-off. The minimum interval between different types of continuous landings in runway mode is shown in Table 1.

Table 1 Minimum interval between different types of continuous landings in runway operation mode.

Aircraft type	The front machine is heavy	The front machine is medium
The rear is heavy	10km	8km
The rear is medium	7km	6km

When the close parallel runway is only used for aircraft landing or take-off, paired approach or paired departure can be used to increase runway capacity. The random error time may be positive or negative, so in order to avoid that the longitudinal interval between two aircraft is not less than the minimum interval stipulated by the regulation, it is necessary to add the pilot's buffer time between the aircraft. When the close parallel runway is used for take-off and landing, considering that the paired operation mode is the approach or departure of aircraft in pairs, and combining with the feasibility of actual operation, the following three operation modes can be used: two landing aircraft and two take-off aircraft run alternately (two in and two out for short); Two landing aircraft and one take-off aircraft run alternately (two in and one out for short); Two take-off aircraft and one landing aircraft run alternately (referred to as one in and two out). The combination ratio of paired models between paired units is shown in Table 2.

Table 2 Combination ratio of paired models between paired units

Pairing type	Combination ratio
Heavy-duty	30.19%
Medium-Medium	27.54%

During a paired approach, the time interval between the paired units is calculated according to the time when the front aircraft of each paired approach plane arrives at the runway entrance, and the time difference between the front aircraft of the two paired units before and after arriving at the runway entrance is composed of the time interval between the front aircraft of the previous paired approach unit and the rear aircraft of the unit and the front aircraft of the next unit. When two runways close to parallel runways are only used for landing, the runway capacity is the landing capacity, and the landing capacity is the reciprocal of the average time interval of landing aircraft at the runway entrance. According to Order No.123, although the rear plane of the previous pairing unit is not on the same runway as the front plane of the next pairing unit, it must be carried out

according to the minimum longitudinal spacing standard of the aircraft approaching in turn on a single runway stipulated by air traffic management. Therefore, the time interval between non-pairing units should be obtained by dividing the front plane speed of the next pairing unit by this longitudinal spacing.

3.2. Runway is only used for capacity model at takeoff.

When two runways close to parallel runways are only used for take-off, the runway capacity is the take-off capacity. At this time, the take-off capacity is the reciprocal of the average time interval of the take-off aircraft at the runway entrance. When studying the arrival capacity of the runway, the calculation of the time interval between two landing planes is the key value, and there are many things to be considered in the calculation process, including the influence of wake interval, the minimum pentagonal distance and so on. Different from paired approach, paired departure planes are released in turn according to time intervals. Assuming that the aircraft take off in the order of M, N, O and P, there are: aircraft M and N leave in pairs, aircraft O and P leave in pairs, aircraft M and O use the same runway, and aircraft N and P use the same runway. According to Order No.123, the release interval between the aircraft in the unpaired unit needs to meet the release interval of the same runway in a single run, while the rear aircraft in the paired departure unit needs to be at the position before the wake of the front aircraft arrives when leaving, so the release interval between a group of paired aircraft is much smaller than the release interval of a single runway.

When two landing aircraft and two taking-off aircraft run alternately on two runways which are close to parallel runways, the two taking-off aircraft can be regarded as the gap between the landing aircraft. By learning from the research experience of single runway capacity model, the probability of meeting the ATC interval is usually 0.95. After consulting relevant information and comprehensive comparison, it is known that two aspects should be taken into account when making relevant calculations: (1) wake standard, that is, the minimum distance standard between continuous landing aircraft; (2) When the rear plane gets permission to land, that is, whether the minimum prerequisite for the distance from the runway entrance before landing, the time the front plane occupies the runway, the length of the runway, the speed of the rear plane, etc. meet the requirements.

4. Conclusions

In this paper, the paired near operation mode is studied, which has certain theoretical reference value for future planning and application of paired near operation mode. Close-parallel runway is one of the key runway types in China's airports, and the application of pairing mode to close-parallel runway can give full play to the advantages of runway to a greater extent. The research on paired operation capacity is still in the initial stage, because the paired operation mode has not been put into practice, so the research on it is still in the theoretical research stage, lacking the actual operation data and experience, which is still a big challenge for researchers in this direction. Further research should be done on the application of paired departure of close parallel runways. The crosswind conditions of airports should be counted, and the utilization rate of paired departure of close parallel runways should be obtained, and the benefits of paired departure of close parallel runways for airports should be quantified concretely. As well as the impact of staggered runway matching with rear aircraft's large-angle approach on the vertical interval and capacity of paired approach, these problems still need to be solved.

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