Demand analysis on the performance of shipboard alert unmanned aerial vehicles

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Abstract. Shipboard alert unmanned aerial vehicles (UAV) has great significance to improve early warning detection capability of aircraft carrier formation. This paper first analyzes and summarizes the tactical and technical indicators of the carrier-based air early warning(AEW), then analyzes the tactical and technical indicators of the UAV refer to technical performance of early warning aircraft, and finally determines the performance indicators of the UAV. Its anterior distance is 400km, the stable working height is 9000m, the maximum level flight speed is 670km/h, and flying time in the mission area is more than 6 hours. It provides a reference for the future test of UAV.

1 Introduction

The shipboard alert UAV focuses on the task of ensuring the aircraft carrier formation to perform mid-to-long sea combat missions. It mainly performs reconnaissance and alert missions to make up or enhance the early alert detection capability of aircraft carrier formations. For catapult takeoff aircraft carrier, alert UAVs can be deployed in the secondary threat direction, and with the use of carrier-based fixed-wing air early warning (AEW). For aircraft carriers that using ski-jump take-off, the alert UAVs can be used with carrier-based alert helicopters to deploy on the periphery of the helicopters. The task of carrier-based alert UAVs is the same as or similar to the carrier-based fixed-wing AEW, so we can put forward the technical specifications from the analysis of the performance characteristics of AEW which provide a reference for the future test of UAV and lay the foundation for the research on the overall performance and thermal cycling parameters of the turbofan engine used in shipboard UAVs.

2 Performance characteristics of carrier-based fixed wing AEW

The main combat mission of carrier-based fixed-wing AEW is to detect and monitor targets from air or sea, to command and guide aircraft to carry out combat missions at the same time. AEW equipped with high-power radar and special electronic equipment, can perform surveillance and guidance missions. It can also reconnoitre enemy outside the enemy air defense area.

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In the development of carrier-based fixed-wing AEW, E-2 was the most successful carrier-based AEW. The aircraft has strong maritime surveillance ability. It usually patrols at a height of 9144m and an attack angle of 3° when performing surveillance missions. It can process hundreds of the tracks and guide intercept dozens batches of aircraft at the same time[1], the main performance indicators was shown in Table 1.

Table 1. The main performance of E-2C.

Main performance	Parameter
Maximum takeoff weight	24687 kg
Maximum level flying speed	626 km/h
Maximum cruising speed	602 km/h
Remote cruise speed	480 km/h
Service ceiling	11278 m
Duration of flight	6.26 h

3 Analysis of Main Performance Requirements of Shipboard Alert UAVs

Operational performance and mission of shipboard alert UAV are very similar with the shipboard AEW, its performance parameters and operational modes can refer to the relevant data of shipboard AEW.

In the air defense of aircraft carrier battle formation, its front configuration should be conducive to improving the overall effectiveness of aircraft carrier formation air defense combat system. In order to increase the depth of early warning detection, the activity area should be as far forward as possible. However, the shipboard alert UAV should make the warning range of the shipboard alert UAV coincide with the existing warning range of the aircraft carrier formation, to form a full depth air early warning detection system.

3.1 Anterior distance analysis

According to the anterior distance mathematical model of warning helicopter established by the related research, when the helicopter airborne radar detection range of 150 km and three generations of aircraft flight speed of 1000 km/h, its anterior distance is between 180 ~ 200 km[2]. The average anterior distance for the shipboard alert helicopter of ‘Sea King’ is 185 km[3], so the anterior distance of alert helicopter is taken at 200 km. In order to maintain early warning detection fan angle of the existing aircraft carrier formations, as shown in figure 1, the anterior distance of shipboard alert UAV should be:

$$\sin(\theta) \leq r_1/d_1 \leq r_2/d_2$$

(1)

where θ is warning detect fan angle, r_1, r_2 are detection distance of shipboard alert helicopter and shipboard alert UAV respectively, d_1, d_2 are anterior distance of the alert helicopter and shipboard alert UAV respectively.

Fig. 1. The anterior distance of UAV.

The low-altitude fighter and low-altitude cruise missiles were found by the radar on shipboard fixed-wing AEW at 410 km and 300 km respectively[4]. Without reducing the fan angle of early warning detection, according to equation (1), the anterior distance of the shipboard alert UAV should not exceed 400 km. And the fixed-wing AEW is usually deployed 400 km before the aircraft carrier formation to perform a task, it is the same distance. If the anterior distance of shipboard alert UAV takes 400 km, the warning distance to low-altitude fighter is 810 km and the warning distance to low-altitude cruise missiles is 700 km.

3.2 Working height analysis

For the detection of cruise missiles and other low-altitude targets, the curvature of the earth restricts the detection range. On the other hand, it is very difficult to detect low-altitude targets from surface clutter which is in the blind spot of air defense radar. For low-altitude targets, the height of the radar determines the radar's limit detection range. The flight altitude of UAV during its mission is usually determined by the mission requirements and the performance of the airborne equipment. At the same time, the effective detection area of airborne radar must cover the area required for combat missions. The effective detection area mainly considers the effective detection range of airborne radar and the direct viewing distance from target affected by the curvature of the earth. The distance between the radar and the target is equal to the geometric direct viewing distance, the geometric distance of the radar is $R_d = 4.12(\sqrt{h_a} + \sqrt{h_t})$. And the shaded area is the radar blind spot, it is mainly affected by the height of the radar[5] as shown in Figure 2.

Fig. 2. The visual distance of radar.

If the distance UAV detecting the three generations aircraft was 350 km and the length of the airborne transmitting antenna was 10 m when the third generation of enemy aircraft attacked at low altitude, the flight height is at least 6689 m when performing an early warning mission based on a geometric direct view formula. The adequate visible transmission distance between the shipboard control station and the alert UAV is required to ensure transmission bandwidth and reliability. If the anterior distance of UAV was 400 km and communication antenna of UAV was 9 m, and the flight height of UAV in the mission area was 8852 m at least. A typical AEW cruised at a height of 9000 m, and the E-2C usually flew at a height of 9144 m with 3° angle of attack during missions. Considering the above situation and keeping a certain margin, the stability working height of alert UAV should be more than 9000m.

3.3 Flight speed analysis

For the shipboard alert UAV, it is very important to reach the mission area and evacuate the dangerous areas quickly, which requires a faster flying speed. If the enemy fighter was detected by the UAV when it was coming to attack the aircraft carrier formation, UAV began to evacuate and the fighter on the aircraft carrier deck began to take off to intercept enemy. To ensure that enemy airplanes were shot down before launching their air-to-air missiles, it must be satisfied:

$$\frac{S_{tc} + S_{jl} - D_d - V_{dj}t_y}{V_{dj} + V_j} + t_{gj} + t_{zb} < \frac{S_{tc} - D_d - V_{dj}t_y}{V_{dj} - V_{wr}} \tag{2}$$

where S_{tc} was detection range of UAV which takes 350 km, S_{jl} was anterior distance of UAV which takes 400 km, D_d was range of air to air missile which takes 120 km, V_j, V_{dj} were carrier-based aircraft speed of ours and the enemy which take 1000 km/h, t_y was the time of alert UAV turn to avoid which takes 2 min, t_{zb} was the preparation time of shipboard aircraft taking off from carrier deck which takes 15 min, t_{gj} was the time from launching missiles to hit the target which takes 1.5min.

In order to ensure that an effective interception can be carried out before an enemy aircraft launches an air-to-air missile on an alert UAV, the flight speed of the UAV should not be less than 671.3 km/h. The maximum level flight speed of the E-2C is 626 km/h, and

the calculated speed is almost same, so the maximum level flight speed of alert UAV is 670 km/h.

3.4 Flying time analysis

Shipboard alert UAV should have a strong ability to endurance, so as to ensure that there are UAVs to carry out the guarding task in the key directions to protect aircraft carrier formation from attack by enemy aircraft during 24 hours. Anterior time T_c and return time T_f of UAV each needs 1 hour, the preparation time T_z needs 1 hour, flying time in the mission area T_d should meet $T_d > T_c + T_z + T_f$, so T_d should be at least 3 hours to ensure that two UAVs rotation to achieve 24-hour vigilance in one direction, as shown in figure 3. If two UAVs were deployed in one direction and the difference between the scheduled time of departure for the two UAVs is three hours, so the minimum T_d should be at least six hours to ensure a rotation of three UAVs and 24-hour vigilance. So flying time in the mission area of alert UAVs should be not less than six hours.

Fig. 3. UAV take turns.

Conclusion

This paper first analyzes and summarizes the tactical and technical indicators of the carrier-based AEW, then analyzes the tactical indicators of the UAV refer to technical performance of AEW, and finally determines the performance indicators of the UAV. It provides a reference for the future test of UAV and lays the foundation for the research on the overall performance and thermal cycling parameters of the turbofan engine used in shipboard UAVs.

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