Regional Ship-to-Air Missile Ship Maneuvering Cover Model

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Abstract — In view of the problem of a regional ship-to-air missile ship covering an adjacent ship, considering the locations of the ships, the required azimuth angle of a regional ship-to-air missile ship covering an adjacent ship, the maximum azimuth angle of a regional ship-to-air missile ship instantaneously covering an adjacent ship, and the remote distance of the regional ship-to-air missile launch area, a model of a regional ship-to-air missile ship longitudinally and laterally maneuvering to cover an adjacent ship was proposed, which provides a model basis for a regional ship-to-air missile ship longitudinally and laterally maneuvering to cover an adjacent ship.

Keywords — Cover Model, Maneuvering, Regional Ship-To-Air Missile, Ship.

I. INTRODUCTION

When a regional ship-to-air missile ship covers an adjacent ship, it can perform longitudinal and lateral maneuvers to cover the adjacent ship.

At present, the main relevant research are as follows: mainly analyze and determine the air defense ship cover sector, mainly analyze and determine the air defense weapon cover angle, mainly evaluate the minimum configuration number parameter of the regional air defense ship, adopt the comprehensive evaluation method to optimize the cover target scheme, mainly determine the air defense fire unit distance, etc.

The above research results do not consider factors such as the locations of the ships, the azimuth angle required by a regional ship-to-air missile ship to cover an adjacent ship, the maximum azimuth angle of a regional ship-to-air missile ship to cover an adjacent ship instantaneously, and the far boundary distance of the ship-to-air missile launch area. Therefore, this paper proposes a regional ship-to-air missile ship maneuvering model to cover an adjacent ship in the longitudinal and lateral directions, which takes into account such factors as the positions of ships, the azimuth angle required by a regional ship-to-air missile ship to cover an adjacent ship, the maximum azimuth angle of a regional ship-to-air missile ship to cover an adjacent ship instantaneously, and the far-off distance of the ship-to-air missile launch area. It can quantitatively provide a model basis for a regional ship-to-air missile ship to cover an adjacent ship in longitudinal and lateral maneuvers.

II. MAXIMUM AZIMUTH ANGLE MODEL FOR A SINGLE REGIONAL SHIP-TO-AIR MISSILE SHIP TO INSTANTANEOUSLY COVER AN ADJACENT SHIP

In Fig. 1, point O is the position of an adjacent ship. The required azimuth range for a single regional ship-to-air missile ship to cover an adjacent ship refers to the required azimuth range for the regional ship-to-air missile ship to cover the adjacent ship, that is, the azimuth range formed by two straight lines, OJ2 and OJ3, with point O as the starting point. Angle H is the azimuth angle required by the regional ship-to-air missile ship to cover the adjacent ship, straight line OJ2 is the azimuth angle line that the regional ship-to-air missile ship needs to cover the adjacent ship, and straight line OJ3 is the azimuth angle line that the regional ship-to-air missile ship needs to cover the adjacent ship. The straight line OJ1 is the reference line, and the angle B is the azimuth angle of the minimum demand angle line for the ship-to-air missile ship to cover the adjacent ship in the area. The Y1 circle is the fire circle of the ship-to-air missile of the adjacent ship, which is a circle with point O as the center and radius E1. E1 is the distance from the ship-to-air missile launch area of the adjacent ship. Point A1 is the instantaneous position of the regional ship-to-air missile ship, and circle A1 is the instantaneous fire circle of the regional ship-to-air missile ship, which is a circle with point A1 as the center and radius E2. E2 refers to the distance from the ship-to-air missile launch area in the area. R is the distance between the point O and the point A1.

Fig. 1. A schematic diagram of the required azimuth range of a single regional ship-to-air missile ship for covering an adjacent ship and the maximum azimuth range instantaneously covering the adjacent ship.

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The maximum azimuth angle at which the regional ship-to-air missile ship can cover the adjacent ship instantaneously refers to the maximum azimuth angle at which the regional ship-to-air missile ship can cover the adjacent ship instantaneously, which is set as angle $U$. It is determined by the instantaneous fire circle of the regional ship-to-air missile ship and the ship-to-air missile fire circle of the adjacent ship, that is, the maximum azimuth angle $U$ formed by the straight line $OJ$ and the straight line $OJ_A$, which constitutes the covering closed area when the regional ship-to-air missile ship instantaneously covers the adjacent ship at the point $A_1$. That is, when the regional ship-to-air missile ship instantaneously covers the adjacent ship at point $A_1$, the circle $A_1$ is tangent to the straight line $OJ_2$ and the straight line $OJ_A$, and the tangent intersections are also at point $C_1$ and point $C_2$ respectively. The intersection points of circle $X_1$ and circle $Y_1$ are also at point $C_1$ and point $C_2$, respectively, forming a covering closed area formed by line segment $OC_1$, line segment $OC_2$ and circle $X_1$. This covering closed area is the largest closed area where the regional ship-to-air missile ship can instantaneously cover the adjacent ship at point $A_1$. The maximum azimuth angle of the covering closed area to point $O$ is the maximum azimuth angle $U$ that the regional ship-to-air missile ship can instantaneously cover the adjacent ship at point $A_1$. $R$ is given in (1), $U$ is given in (2).

\[ R = \sqrt{E_1^2 + E_2^2} \quad (1) \]

\[ U = 2\arcsin \left( \frac{E_2}{\sqrt{E_1^2 + E_2^2}} \right) \quad (2) \]

III. A MODEL OF LONGITUDINAL MANEUVER FOR A SINGLE REGIONAL SHIP-TO-AIR MISSILE SHIP TO COVER AN ADJACENT SHIP

On the basis of Fig. 1, when the required azimuth angle $H$ of the regional ship-to-air missile ship for covering the adjacent ship is smaller than the maximum azimuth angle $U$ of the instantaneous covering the adjacent ship, (see Fig. 2). The straight line $OJ_A$ is the center line of the angle range of the adjacent ship covered by the regional ship-to-air missile ship. When the regional ship-to-air missile ship covers the adjacent ship, the regional ship-to-air missile ship can make longitudinal maneuvers on the straight line $OJ_A$. Set a point $A_2$ on the straight line $OJ_A$, and the point $A_2$ is the instantaneous position of the regional ship-to-air missile ship. The $X_2$ circle is also the instantaneous fire circle of the regional ship-to-air missile ship, which is a circle with point $A_2$ as the center and radius $E_2$. The $Y_1$ circle and the $X_2$ circle intersect on the straight lines $OJ_2$ and $OJ_3$. The $Y_1$ circle and the $X_2$ circle intersect on the straight line $OJ_2$ at point $C_3$, and the $Y_1$ circle and the $X_2$ circle intersect on the straight line $OJ_3$ at point $C_3$. It constitutes the covering closed area formed by the line segment $OC_3$, the line segment $OC_5$ and the circle $X_2$ that is the closest to point $O$ when the regional ship-to-air missile ship instantaneously covers the adjacent ship at point $A_2$. This covered area is the closest closed area when the regional ship-to-air missile ship can instantaneously cover the required azimuth angle $H$ of the adjacent ship. Set point $A_3$ on the straight line $OJ_3$, and point $A_3$ is the instantaneous position of the regional ship-to-air missile ship. The $X_3$ circle is the instantaneous fire circle of the regional ship-to-air missile ship, which is a circle with point $A_3$ as the center and radius $E_3$. The $X_3$ circle is tangent to the straight line $OJ_3$ and the straight line $OJ_4$, and the tangent intersections are points $C_4$ and $C_5$ respectively. It constitutes the covering closed area farthest from point $O$, formed by the line segment $OC_4$, the line segment $OC_5$ and the circle $X_3$ when the regional ship-to-air missile ship instantaneously covers the adjacent ship at point $A_3$. This covered closed area is the farthest closed area when the regional ship-to-air missile ship can instantaneously cover the required azimuth angle $H$ of the adjacent ship. The intersection of the straight line $OC_4$ and the straight line $OJ_4$ is a point $C_5$.

Therefore, the regional ship-to-air missile ship can make longitudinal maneuvers on the straight line $OJ_4$ to cover the adjacent ship, and its longitudinal maneuvering range is the line segment $A_2A_3$ from point $A_2$ to point $A_3$. $|OA_2|$ is given in (3).

\[ |OA_2| = \sqrt{E_2^2 - E_3^2 \sin^2(0.5H)} + E_1 \cos(0.5H) \quad (3) \]

The distance between point $A_2$ and point $O$ is $|OA_2|$ and the relative angle is $B + 0.5H$. The distance between point $A_3$ and point $O$ is $|OA_3|$, and the relative angle is $B + 0.5H$. $|OA_3|$ is given in (4).

\[ |OA_3| = \frac{E_2}{\sin(0.5H)} \quad (4) \]

![Fig. 2. A schematic diagram of a regional ship-to-air missile ship's longitudinal maneuver for covering an adjacent ship.](image-url)
IV. A MODEL OF LATERN MANEUVER FOR A SINGLE REGIONAL SHIP-TO-AIR MISSILE SHIP TO COVER AN ADJACENT SHIP

On the basis of Fig. 1, when the required azimuth angle $H$ of the regional ship-to-air missile ship for covering the adjacent ship is greater than or equal to the maximum azimuth angle $U$ of instantaneously covering the adjacent ship, see Fig. 3. Point $A_4$ is also the instantaneous position of the ship-to-air missile in the area. The $X_4$ circle is also the instantaneous fire circle of the regional ship-to-air missile ship, which is a circle with point $A_4$ as the center and radius $E_2$. The $X_4$ circle is tangent to the straight line $OJ_3$, and the tangent intersection point is point $C_9$. The angle $H_1$ is the included angle between the straight line $OA_4$ and the straight line $OJ_3$.

When the regional ship-to-air missile ship covers the adjacent ship, it needs to implement lateral maneuvers in Fig. 3. That is, the regional ship-to-air missile ship can make a lateral maneuver on the arc $S$ with the point $O$ as the center and the radius $R$, and the lateral maneuver range is the arc segment $A_4A$ from the point $A_4$ to the point $A$. The azimuth angle of the arc segment with respect to the point $O$ is $H_1$. It constitutes a covering closed area formed by the line segment $OC_9$, the line segment $OC_9$ and the instantaneous fire circle of the regional ship-to-air missile ship when the regional ship-to-air missile ship covers the adjacent ship in this arc segment. The covering closed area is the closed area when the regional ship-to-air missile ship can instantaneously cover the required azimuth angle of the adjacent ship. Where the distance between the point $A_4$ and the point $O$ is $R$ and the relative angle is given in (5).

$$\angle A_4OJ_3 = B + \arctg(E_2/E_1) \tag{5}$$

The distance between point $A_4$ and point $O$ is $R$ and the relative angle is given in (6). $H_1$ is given in (7).

$$\angle A_4OJ_1 = B + H - \arctg(E_2/E_1) \tag{6}$$

$$H_1 = H - 2\arctg(E_2/E_1) \tag{7}$$

Fig. 3. A schematic diagram of a regional ship-to-air missile ship's lateral maneuver for covering an adjacent ship.

V. CONCLUSION

On the basis of considering the positions of the ships, the required azimuth angle of the regional ship-to-air missile ship to cover the adjacent ship, the maximum azimuth angle of the regional ship-to-air missile ship to instantaneously cover the adjacent ship, and the far distance of the ship-to-air missile launch area, the longitudinal and lateral maneuvering cover model for a regional ship-to-air missile ship to cover an adjacent ship is proposed in this paper, which provides a basis for the regional ship-to-air missile ship to cover adjacent ship in the longitudinal and lateral maneuvers.

REFERENCES

[1] Ji Z, Wang YT, Han Y. Analysis of Medium-Range Anti-Aircraft Vessel Cover Fan in Aircraft Carrier Formation, Command Control & Simulation, 2019; 41(3): 24-29.
[2] Dai J, Li XM, Bo N, Wu XH. Assessment Method of Covering Capability of Ground Air Defense Weapon during Point Air Defense Combat. Modern Defense Technique, 2018; 46(4): 1-7.
[3] Lu XQ, Li N, Chen G. Covering Angle Analysis of Anti-missile Deployment. Fire Control & Command Control, 2014; 39(7): 85-88.
[4] Lu XQ, Zhang XK. Covering Capability Analysis of Terminal High Altitude ATBM System. Aerospace Control, 2014; 32(2): 41-45.
[5] Jia ZJ, Dong SQ. Analysis on Deployment of Warship in Supporting Reef Air Defense. Command Control & Simulation, 2022; 44(2): 24-28.
[6] Ji FB, F. Xiang FF, Guan YY. Research on Air Defence Disposition for Formation of Aircraft Carrier. Ship Electronic Engineering, 2012; 32(11): 1-3.
[7] Huo L, Gu XY, Zhang X, Chen B, Tan HD. Anti-Aircraft Weapons in a Position Allocation Model. Ordnance Industry Automation, 2012; 26(10): 32-33.
[8] Gao YQ, Tong YT, Li LW, Ju W. Research on the Position of Medium-Range Air-defense Ship in Surface Ship Formation. Tactical Missile Technology, 2010; (3): 41-43.
[9] Zhao T, Zeng QT. Analysis of the Auxiliary Decision Model of the Anti Cruise Missile Position Configuration of the Anti Aircraft Gun Group. Journal of Ordnance Equipment Engineering, 2009; 30(11): 75-77.
[10] Cao L, Wang HY, Lu FX. Research on Configuration Method of Air Defense Ships Based on Cover Operational Capability. Journ, Oct. 2019.
[11] Yang Q, Jiang H, Cheng HQ. Fixing of Key Covered Object for Air Defense Based on Collected Value Statistic. Ordnance Industry Automation, 2006; 25(7): 5-7.
[12] Song ZL, Wang YL, Wang YL. Covered Targets Priority of the City Air Defense Based on Information Entropy and TOPSIS Method. Command Control & Simulation, 2010; 32(3): 22-23.
[13] Zhou L, Liu SL, Huang SC, Liu QZ. Application of AHP in Determining Important Protection Project. Ordnance Industry Automation, 2007; 26(2): 8-10.
[14] Liu WT, Dan ZC, Li HT, Hou ZT. Optimized Evaluation of the Disposition of the Missile-Gun Combined Air Defense. Fire Control & Command Control, 2006; 31(10):58-61.
[15] Xu CJ, Wang LQ. Optimizing and Sequencing of the Important Defended Targets in Air-defense Operation based on Interval-number. Fire Control & Command Control, 2010; 35(3):154-156.
[16] Sun JW, Jia CY. Research on Air Defense Group Fire System. Modern Defence Technology, 2008; 36(4): 88-92.
[17] Wang K, X. Yuan XB, Lu ML. Study on the Optimizing of Surface-to-air Missile Forces Disposition Project. Ship Electronic Engineering, 2010; 31(6): 37-41.
[18] Tang SJ, Lu JW, Zhou P. Research on Determining the Protecting Focal Project Based on Momentum BP-NN. Command Control & Simulation, 2006; 28(5): 81-85.
[19] Xu SL, Jiang QS, Wang HZ, Zhang PZ. Simulation Research on the Battle Field of Coverture-veil Anti-aircraft Vessel for the Aircraft Carrier Formation. Ship Electronic Engineering, 2008; 28(9):146-149.
[20] Wang J, Jiang SC, Wang YL, Wu FW. Quantitative analysis of deployment distance between fire units based on the composite disposition of the air defense missiles. Systems Engineering and Electronics, 2006; 28(2): 263-265.