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# Investigation of Aerodynamic of Expand Folding Rudder Separator Delivery from Cavity

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**Abstract**

In the subsonic, transonic and supersonic wind tunnels, the launching test technology of the buried separators in folding rudder separator is studied. In view of the two different folding modes of the Separator rudder surface, two testing techniques are developed for the horizontal folding and vertical folding of the rudder surface, which can ensure the self locking function before and after the rudder surface is unfolded. The folding and unfolding state is not affected by the start impact of the wind tunnel and the turbulence. At the same time, the position of the rudder surface is expanded to achieve the real launch and expansion of the simulated separator. The developed dual angle of view, high brightness optical path system and six degree of freedom image analysis system can obtain the full trajectory image and aerodynamic parameters of the projectile embedded in the aircraft. The test technology can independently adjust the ejection speed and angular velocity of the release material, and can study the influence of different separation conditions on the separation safety. The non-expansion test technology of the rudder surface has completed the wind tunnel test verification under the condition of supersonic velocity and multi-body interference and complex aerodynamic force, which meets the demand of the launch and wind tunnel test research.

**Keywords**

High speed separator delivery, Folding rudder separator, Separator firing from cavity, Carrier and separator interference, Multi-bodies separation, Six degree of freedom

## Introduction

Delivery from cavity has many advantages, including reducing the rate of radar discovery, reducing the aerodynamic drag and increasing the range of the bomber [1-4]. However, the size of the interior of the aircraft is often limited. How to make better use of the space in the cabin and as much as possible to mount the separator is an important means to evaluate the level of the combat effectiveness of the aircraft. At the same time, in order to make the separator flight more flexible and controllable, the steering surface of the separator is often relatively large. The rudder surfaces are also out of the separators [5,6], occupies too much space in the cabin when the separator is suspended in the cavity, causing the extreme waste of the space in the cabin and greatly reducing the combat effectiveness of the aircraft. The folding rudder is

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a good way to save space and increase the loading number of the separators, and has been successfully applied to separators [7-9], such as the folding rudder used for shipborne separator, the roll arc wing used by the antitank projectiles. The space of the airborne embedded projectile is limited, and if the folded rudder is applied to the embedded Separator, it will make full use of the limited space in the cabin to greatly improve the operational capability of the fighter.

There is still uncertainty in the launching of the fixed rudder surface Separator [10-14], and the folding rudder Separator needs to carry out the unfolding of the rudder when it is close to the machine. The launching of the rudder must cause the change of the aerodynamic force and torque of the projectile, and the trajectory of the Separator is difficult to be determined [15-18]. A series of complex conditions are added to the complex flow interference area, making the separation characteristics of the folded rudder Separator more difficult to determine [19-23]. Therefore, it is very necessary to carry out dynamic test research on the factors affecting the deployment of buried separators in folding rudder separator.

## Technical Difficulties

### Ejection technology

We need to solve the problem that the model hangs. It is well known that the impact load of the wind tunnel is very large. For dynamic test, the model mechanism is active, which requires that all the moving parts before the test start to lock themselves to prevent the impact load to start the test mechanism and cause the failure of the test. Specifically, the moving parts of the project include the Separator launching mechanism and the rudder folding rudder deployment mechanism. The 2 parts require self-lock and unlocking design; especially the folding rudder needs to simulate real launch process, not only need self-lock before unfolding, but also require locking function after unfolding. It is easy to imagine the difficulties of designing so many functions small separators, which just like a ballpoint pen.

The model ejection $v$ and $\omega$ need to be independent and continuously adjustable. This requires the ejection mechanism to have the ability to adjust the ejection speed and angular velocity independently, which puts forward a very high demand for the reliability of the separation mechanism.

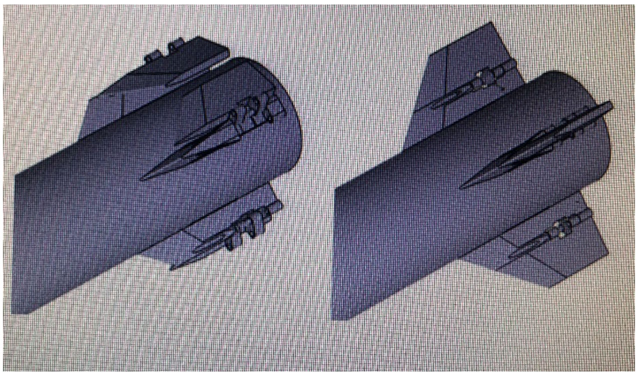

**Figure 1:** Folding and unfolding of parallel folding rudder surface.

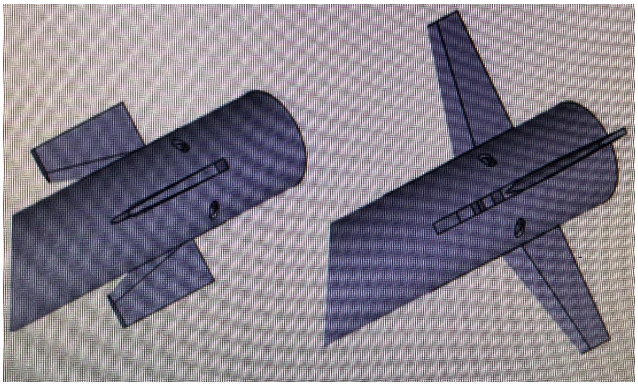

**Figure 2:** Folding and unfolding of vertical folding rudder surface.

### Folding rudder unfolding technology

The model ejection velocity and angular velocity need to be independent and continuously adjustable. In order to solve the problem that the separator can hold, the problem that the separator can be unlocked when it needs to be unlocked should be solved, and the speed and angular speed of the separator should have certain accuracy. At the same time, in order to find the appropriate separation velocity and angular velocity, the separation velocity is usually fixed and adjusted separately in the test, which requires the ejection mechanism to have the ability to independently adjust the ejection velocity and angular velocity, which puts forward a very high requirement for the reliability of the separation mechanism.

The foldable rudder can be divided into 2 types: Parallel folding rudder and vertical folding rudder. Parallel is parallel to the axis of the projectile body, as shown in Figure 1. The vertical folding refers to the vertical axis of the steering axis and the axis of the body, as shown in Figure 2.

## Solution and Implementation Plan

### Ejection mechanism

The ejection speed is provided by a single cylinder. On the basis of the ejection mechanism, the angular velocity adjustment device is designed to realize the independent continuous regulation of the ejection velocity and angular velocity of the model. When the ejection cylinder moves down the ejection model, the angular velocity regulator works at the same time, making the model have the presupposed ejection speed and angular velocity at the moment of departure from the ejection frame.

The model adopts hole pin coordination, opening holes in the model hooks, and opening holes in the corresponding positions of ejection rack points. After the model hole corresponds to the hanging hole, the steel wire is locked. The principle of its control is that the cross section of the projectile is "7" shape. A "L" lever is designed on the catapult hanger. After the hanger is hung up, the ejection frame is moved up with the ejection frame. After the ejection frame is moved up, the piston rod is locked with the bolt. At this time, the "L" lever on the hanger has turned in place in the movement and just locked the bomb. The "7" type hook on it. The model is locked. When ejection, the piston bolt is pulled out, the ejection rack moves down, the "L" lever is returned, and the contact is disconnected from the "7" type hook on the projectile, and the model is unlocked.

Table 1 shows the test results and accuracy of ejection for 3 consecutive ejection stages. The expected ejection angle is 300 degrees/sec and the speed is 2.28 m/s. we can see that the speed and angular velocity error of the ejection mechanism for 3 consecutive ejection separator meet the technical requirements, with a repetition rate of 100%. The speed, angular velocity, error and repeatability of the test set meet the technical requirements.

### Rudder surface expansion technology

In the design of parallel folding rudder, the model folding tail rudder is locked with a ring card. It can resist the turbulence started by the wind tunnel and use the pullout to trigger the unfolding of the rudder surface. When the folding rudder model is separated from the distance from cavity, the pullout line reaches the limit length, thus pulling out the pin out and triggering the moving mechanism within the projectile. The folding rudder is expanded, and the folded rudder is expanded by the reserved torsional force of the spring to prevent the airflow from blowing and folding the expanded rudder. At the same time, it is necessary to explain that the center of mass of the separator is removed and the high degree of finish is removed, which minimizes the effect of the drawing operation on the movement of the projectile. Figure 3 and Figure 4 show the test images of two test models in windless state. To verify the feasibility of model unlocking and rudder deployment test technology.

### Image data analysis method

The desired image is obtained through background subtraction, median filtering, shadow removal, mathematical morphology processing and connected domain analysis. The x, y, z coordinates, pitch angle and yaw angle of the centroid of the model are identified through the elevation and elevation view, and the rolling angle of the model is obtained by model matching.

Image recognition is a key technology of this test technology, which is affected by factors such as image definition, pixel location, target location method and model boundary recognition algorithm.

As the direct source of data analysis, the accuracy of model angle identification is higher and the accuracy of data analysis is more accurate. As shown in Table 2, the accuracy of this attack angle analysis can be controlled within 0.2 degrees. The true value is the true angle value of the fixed attack angle of the model, and the identification value is the angle value identified after the camera is captured.

**Table 1:** The results of ground test.

| Serial number | Speed (m/s) | Angular velocity (degree/s) | Speed error | Angular velocity error |
|---|---|---|---|---|
| 1 | 2.284 | 302.6 | 0.16% | 0.88% |
| 2 | 2.256 | 281.7 | 1.03% | 6.08% |
| 3 | 2.256 | 285.9 | 1.03% | 4.69% |

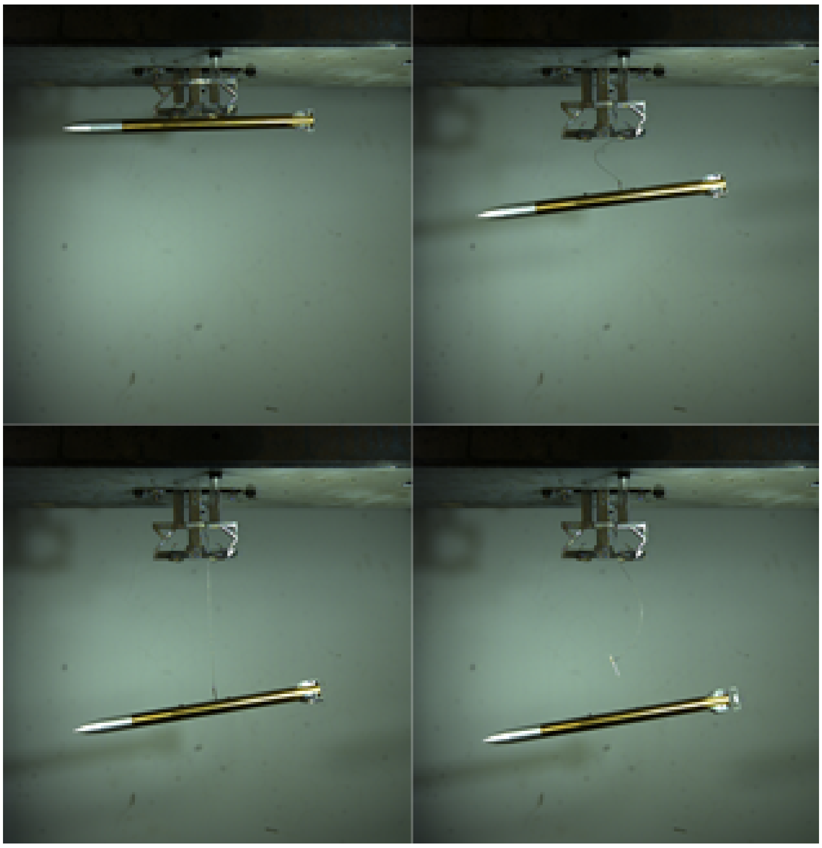

**Figure 3:** Horizontal folding rudder unfolding test.

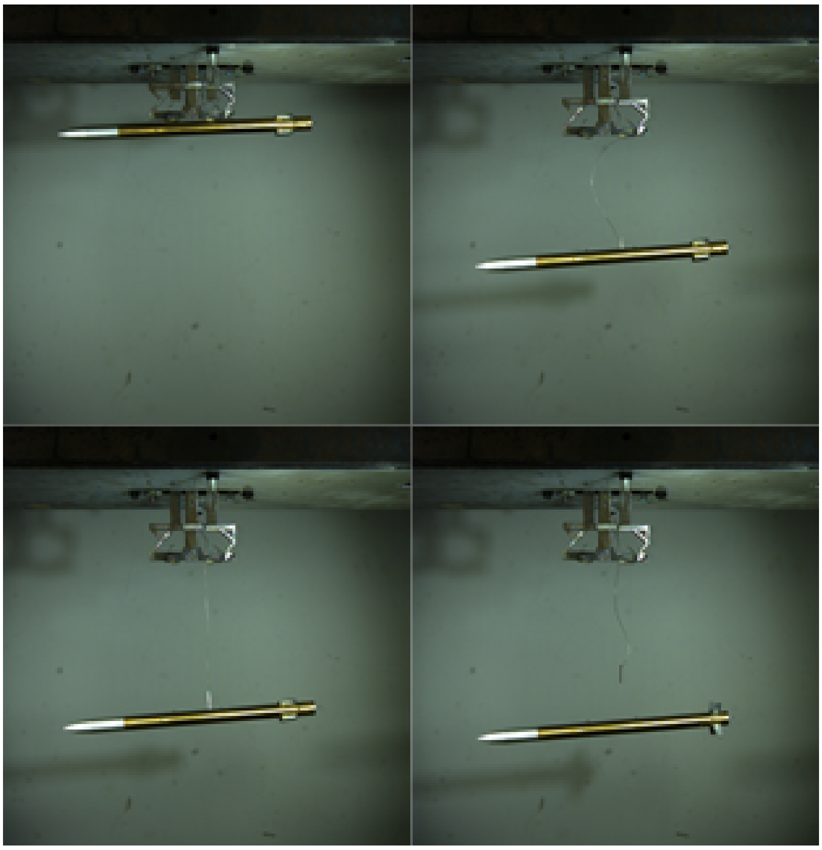

**Figure 4:** Vertical folding rudder expansion test.

**Table 2:** The precision of attack angle.

| Serial number | Truth value (degree) | Identification value (degree) | Precision (degree) |
|---|---|---|---|
| | -8.00 | -7.86 | -0.14 |
| | -4.00 | -4.18 | 0.18 |
| | -2.00 | -2.14 | 0.14 |
| | 0.00 | 0.09 | -0.09 |
| | 2.00 | 1.90 | 0.10 |
| | 4.00 | 4.17 | -0.17 |
| | 8.00 | 8.12 | -0.12 |

## Reliability Test

In order to verify the reliability of ejection technology, an ejection wind tunnel test was designed. The test site is shown in Figure 5.

The test has successfully completed the scheduled tasks, and all the parameters have met the requirements of setting technical specifications. The independent and continuous adjustment of ejection speed and angular velocity is realized, and the reliable ejection of separator with arbitrary wind loads and Ma is realized. As shown in Figure 6.

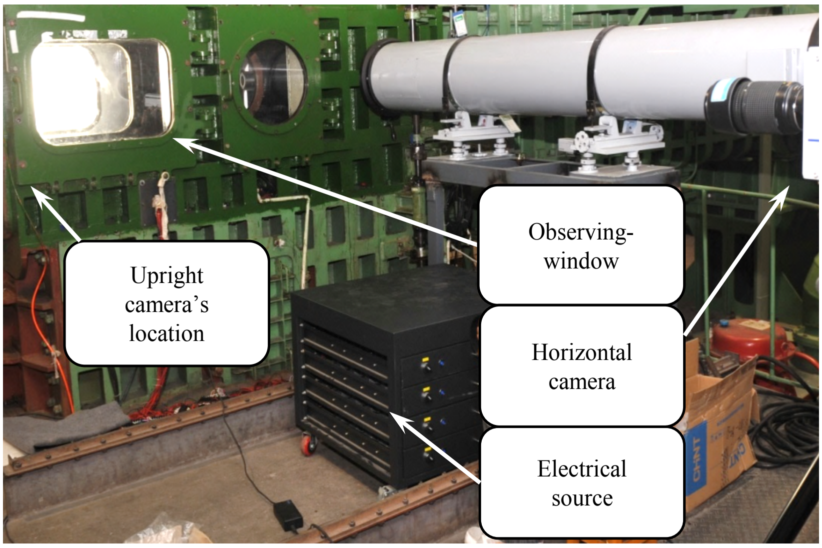


**Figure 5:** The test site.

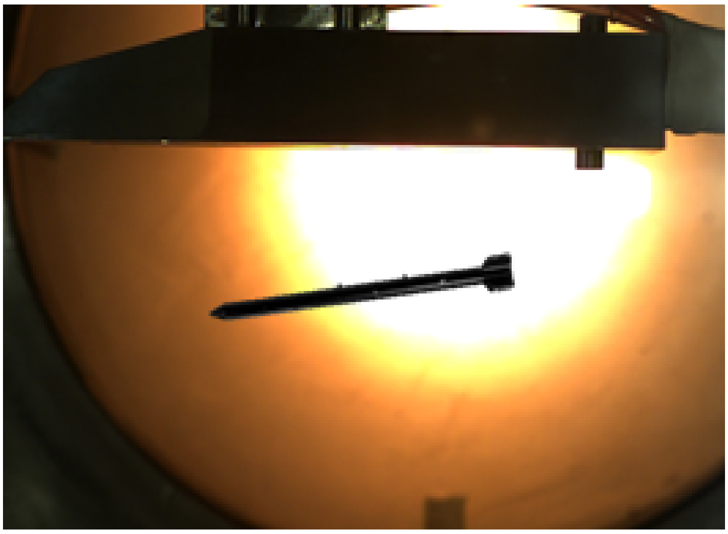

**Figure 6:** The picture shoot by horizontal camera.

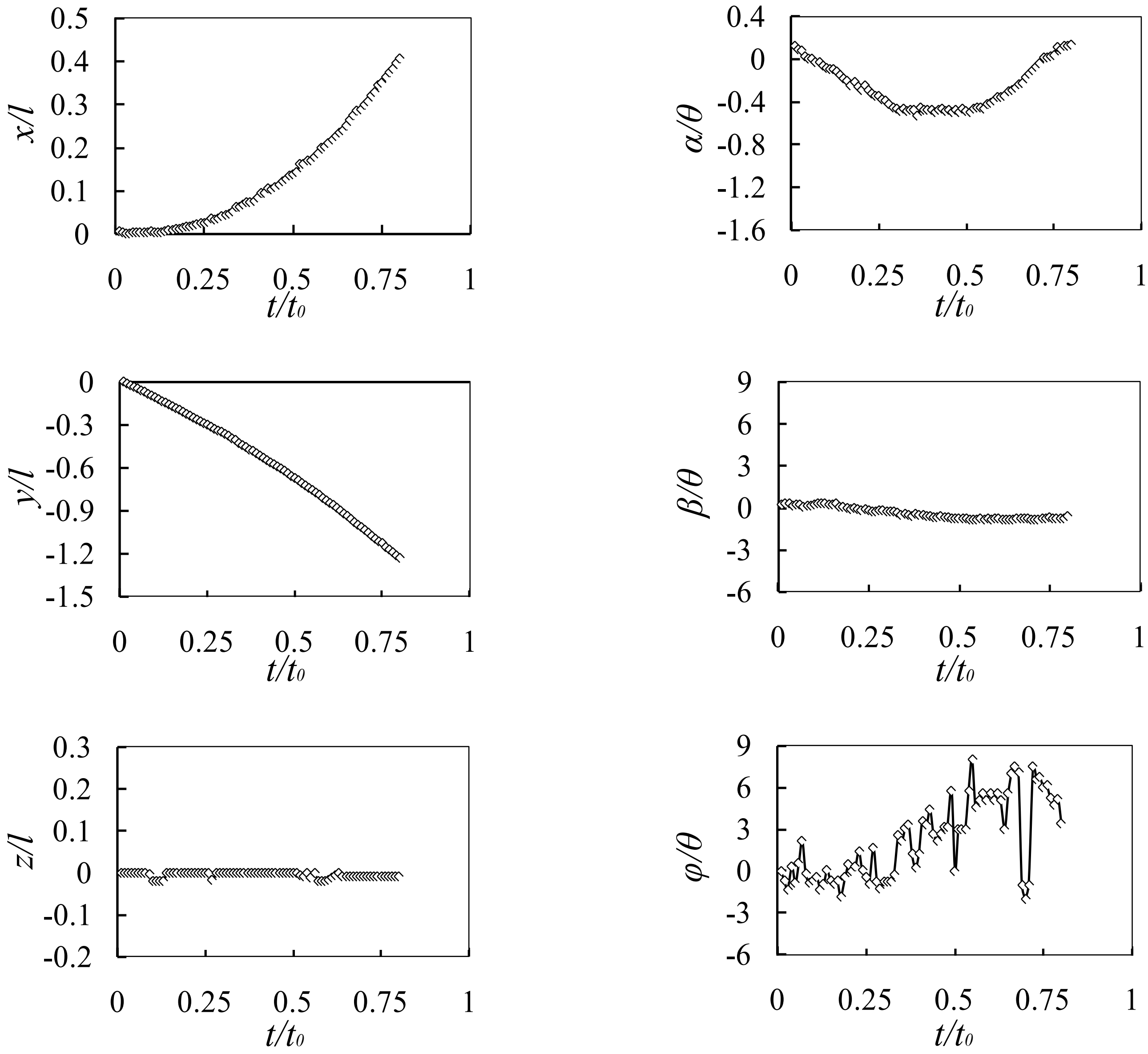


**Figure 7:** Curves of 6 DOF parameters changing with time.

As can be seen from Figure 7, the main trajectory of separation is to move to the lower and rear parts of the aircraft. The motion characteristics are as follows: lateral motion is not obvious; Yaw motion is not obvious; pitch motion is significant. Under the effect of initial bow angular velocity, the missile bows its head first, and then returns to zero under the effect of its own stability. The experimental model has certain roll characteristics.

## Conclusion

In this paper, aiming at two different folding modes of the steering surface of the Separator, this paper designs and tests two kinds of testing techniques of horizontal folding and vertical folding of the rudder surface, which can ensure the self-lock function before and after the rudder surface is unfolded. The folding and unfolding state is not affected by the impact of the wind tunnel starting and the turbulence. The deployment ability of the rudder at the predetermined position of the aircraft is achieved.

Through the use of the latest ejection scheme, the speed and angular velocity of the embedded separator are continuously adjustable, and the reliability of the technology is tested successfully in the subsurface hyper flow field. By improving the light path lighting system, the image clarity is higher, the image virtual shadow is reduced, and the identification of the Model 6 degree of freedom parameters is favorable. The use of dual angle image acquisition technology, especially the layout of the upward looking optical path system, shows the details of the model movement to the greatest extent from many angles. The wind tunnel test is carried out for the launching mechanism.

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