Defence Technology 13 (2017) 206–211

Contents lists available at ScienceDirect

Defence Technology

journal homepage: www.elsevier.com/locate/dt

Optimal design of the aerodynamic parameters for a supersonic two-dimensional guided artillery projectile

Ke Liang [a,*], Zheng Huang [a], Jing-min Zhang [b]

[a] Xi'an Institute of Electromechanical Information Technology, Norinco Group, No.99 Jixiang Road, Xi'an 710065, Shaanxi, China
[b] No.208 Research Institute of China Ordnance Industries, 1023 Changping, Beijing 102202, China

ARTICLE INFO

Article history:
Received 24 January 2017
Received in revised form
30 March 2017
Accepted 10 May 2017
Available online 10 May 2017

Keywords:
Two-dimensional guided projectile
Aerodynamic parameters
Canard profile
Numerical simulation
Optimal design

ABSTRACT

An optimization method is introduced to design the aerodynamic parameters of a dual-spin two-dimensional guided projectile with the canards for trajectory correction. The nose guidance component contains two pairs of canards which can provide lift and despin with the projectile for stability. The optimal design algorithm is developed to decide the profiles both of the steering and spinning canards, and their deflection angles are also simulated to meet the needs of trajectory correction capabilities. Finally, the aerodynamic efficiency of the specific canards is discussed according to the CFD simulations. Results that obtained here can be further applied to the exterior ballistics design.

1. Introduction

As improving artillery projectile accuracy is obviously beneficial for the fire efficiency, nowadays the precision-guided munitions are of interest to the Army as a means of both reducing collateral damage and increasing the chance of desired effect with the first round fired [1,2].

In this paper, some fundamental studies on the structural and aerodynamic features for the guided projectile in the preliminary design of its exterior ballistics were discussed. There were many previous works that were contributed to the methods involved in this paper. Theodoulis et al. introduced the guidance and control modules for a class of spin-stabilized fin-controlled projectiles[[3–6], and the complete nonlinear dynamical model is developed and analyzed. Chang et al. analyzed the impact of the spin-rate on the forward section of the trajectory, their results indicated that the spin-rate property is influenced by the canards actuation [7–9]. As the dual-spin guided projectiles are fundamentally less stable than the conventional ballistic spin-stabilized projectiles, Wernert et al. modelled and analyzed the stability conditions of the guided projectiles [10,11]. Hamel, Youn, Sahu and et al. studied the aerodynamic characteristics of different kinds of trajectory correction projectiles [12–14]. Those studies gave us the ideas to design, model and analyze the complicated dynamics of the guidance and control system of the guided projectile. In particular, they provided some helpful references to investigate the aerodynamic characteristics in the preliminary design.

The purpose of this work is to design the control canards for the dual-spin two-dimensional guided projectile. An optimal design method was developed in this paper to obtain the aerodynamic parameters of the control canards for trajectory correction. Numerical simulations were performed to study the aerodynamic efficiency of the guided projectile with control canards.

2. Model and method

2.1. Model of the 2-D guided artillery projectile

The two-dimensional guided projectile in this study includes a conventional 155 mm projectile body and a nose guidance component which is used for trajectory correction. The design model the two-dimensional guided projectile is shown in Fig. 1. There are two pairs of canards fixed on the nose component of the projectile. The first pair of canards, called the steering canards, is mounted in the same direction on the nose component to create lift

* Corresponding author.
E-mail addresses: liangke3039@163.com (K. Liang), huangzheng82369@163.com (Z. Huang), zjm_208suo@163.com (J.-m. Zhang).

Peer review under responsibility of China Ordnance Society

http://dx.doi.org/10.1016/j.dt.2017.05.003

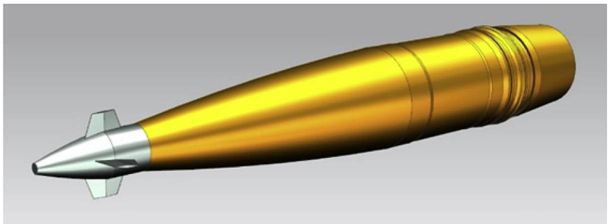

Fig. 1. Two-dimensional guided projectile.

force. Meanwhile, the second pair of canards, named the spin canards, is differentially canted in a manner to create a sufficient amount of moment to rotate the head component in an opposite direction of the projectile spin.

2.2. Optimal design method

In design of the Two-dimensional guided projectile, it is absolutely essential that the aerodynamic parameters for different canard wings' structures are analyzed and optimized. Therefore, the optimal aerodynamic configuration can be obtained, and as well as the required correction forces and moments can be guaranteed. In detailed design, several designed parameters, such as the wing area, the profile, the aspect ratio, the sweepback angle and the taper ratio, are indispensable for influencing the aerodynamic configuration of the projectile.

The general guideline of the wing area design is to provide the necessary trajectory correction ability as much as possible in the limited shape space. As the changes of aerodynamic configuration are comparatively limited due to the restraints both from the shape of the projectile and the lift force of the canard wing, the study of the trajectory correction ability is focused on the calculations of additional force and additional moment about the projectile with corrective canards. By adding the additional forces and moments to the equations of motion [15], the trajectory correction abilities with respect to the different wing areas can be investigated.

There are two types of profile that can be divided as the supersonic profile and the subsonic profile in application. For the frequently used supersonic profiles, such as diamond shape, lens shape, hexagon and blunt trailing edge, their features are simply shaped airfoils with sharp leading edges to cut down the shock wave. For the subsonic profiles, such as symmetric arc, asymmetric arc and laminar flow, they are usually streamlined with relatively smooth leading edges to enhance the leading-edge suctions and to reduce the atmospheric drags.

While increasing the aspect ratio, generally, the slope of lift curve will be elevated. For a specific length of the wing root, both the span and the aspect ratio will be raised at the same time. However, the span must not exceed the caliber of the artillery. The length of mean chord will decrease while the friction will increase, and the wave drag will also increase for a low mach number during the supersonic flying.

The sweepback angle will mainly impact the resistance property of the projectile. The reasons for using the sweepback angle are to increase the critical mach number, delay the shock wave, decrease the peak value of the drag coefficient and make the drag coefficient change smoothly with the increasing of the mach number. The taper ratio has less influence on aerodynamics of the projectile when the other geometric parameters had been finalized.

Changing of any mentioned parameters above will affect its aerodynamic efficiency of the 2-D guided projectile. In order to obtain the optimal aerodynamic configuration, both the constraint of the structural strength and the adjustment of the canard's aerodynamic shape should be considered. In this study, the optimal design algorithm is developed by coupling of the fluid and solid, as shown in Fig. 2, which make sure the aerodynamic efficiency to be optimized under all the given requirements.

From Fig. 2, there are two types of parameters need to be optimized for selecting the canards, which are structure parameters and aerodynamic parameters. Meanwhile, there are strong connections between these two types of parameters. Firstly, we calculated the structure parameters, such as parameters of the profile, by using engineering prediction methods, and made those results as the initial inputs of the optimization process. Then, the aerodynamic parameters are simulated and optimized to meet the trajectory correction capability of the guided projectile. During the optimizing process, both the structure parameters and aerodynamic parameters might be redesigned under their boundary conditions. And finally, the local optimal solution can be obtained as well as the canards can be selected.

After the optimization method is used to obtain the profiles of steering or spinning canards, the relationship between the deflection angle of control surface and the angle of attack can be

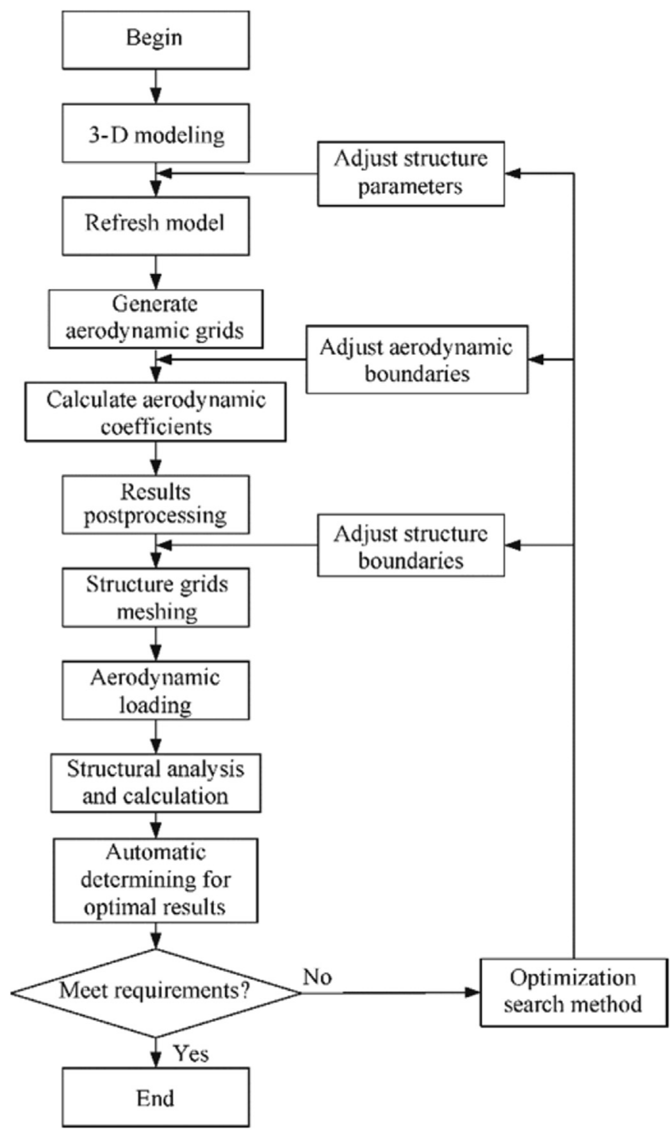

Fig. 2. Optimal design algorithm of 2-D guided projectile with high aerodynamic efficiency canards.