Aerodynamics Characteristics of Hypersonic Vehicle in Near Space

Wu.Dingyi Liu.Zhenxia Xiao.Hong
School of Power and Energy, Northwestern Polytechnical University, Shaan'xi 710072
Email address :xhong@nwpu.edu.cn

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Abstract

The purpose of the current study is to examine the aerodynamic characteristics of two hypersonic ve hicles in near space . One is derived from waverider shape, and the other from liftbody. The objective of this study are threefold. The first is to creat an comput ational database for hypersonic vehicle configurations. The second is to examine the effects of individual veh icle components on hypersonic configurations and to determine the differences in aerodynamic characterist ics that result from integrating all vehicle components. The third objective is to evaluate the controllability of each of the fully integrated vehicles and the effective ness of the control surface design. These objectives w ere accomplished using DSMC solutions and aerody namic code developed in Northwestern Polytechnical University. The results are analyzed also in three sect ions. First, the results of the waverider shape and lift body shape without integrated vehicle components are presented. Second, the results of adding aircraft comp onents to the waverider shape and liftbody shape are presented. Finally, the aerodynamic characteristics of the fully integrated waverider-derived configuration and liftbody-derived configuration are examined and compared with those of the pure waverider shape and liftbody shape. Comparation between fully integrated waverider-derived configuration and liftbody-derived configuration are also presented in this paper.

1 Hypersonic Configuration Design

Two configurations have the same shap in the the centerline profile and the shape is plotted in Fig.1.

The forebody and inlet's integrated design are described in Ref.5. The nozzle and afterbody design are described in Ref.13.

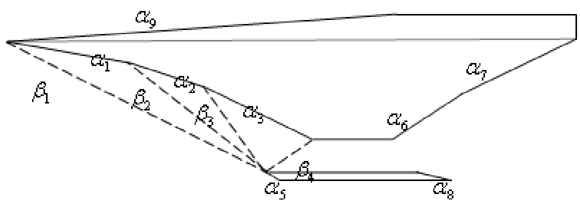

Fig.1 Centerline profile shape of two hypersonic configuration

In this paper, the design mach number is defined as 6.0 and the shockwave angle are defined as floowing

$$\beta_1 = \beta_2 = \beta_3 = 13^0$$

$\alpha_1, \alpha_2, \alpha_3$ are calculated by mach number and shockwave angle.

$$\alpha_4 = \alpha_1 + \alpha_2 + \alpha_3$$

So, the shockwave angle β_4 are calculated.

Other parameters are defined as flowing that

$$\alpha_5 = 5^0, \alpha_6 =, \alpha_7 =, \alpha_8 =, \alpha_9 =,$$

The top view shape of two configuration is plotted in Fig.2.

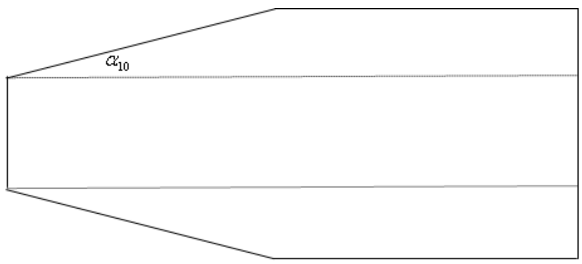

Fig.2 The top view shape of two hypersonic configuration

The difference of two hypersonic configuration is the bottom surface except the pre compress surface.

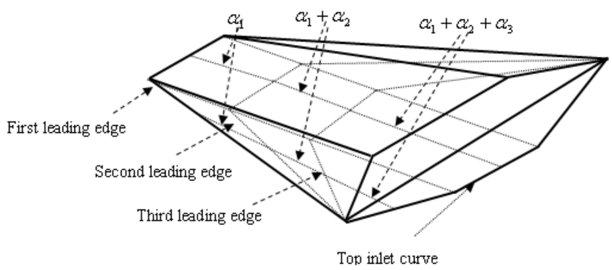

Fig.3 Waverider shape configuration forebody

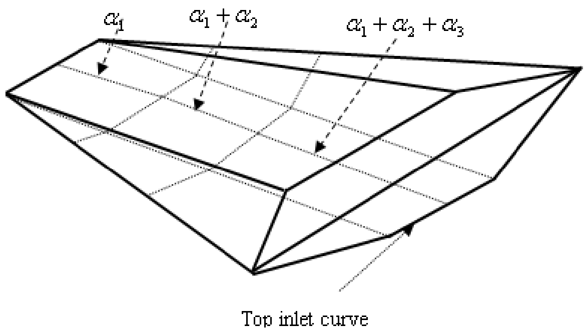

Fig.4 Liftbody shape configuration forebody

Parameters used in design of two configuration are given in Fig.3 and Fig.4. Steps of the design are given in Ref.1.

The design goal of waverider forebody is that forebody have three attached shockwave in the design flight condition.

Three hypersonic inlets are designed by same parameters.

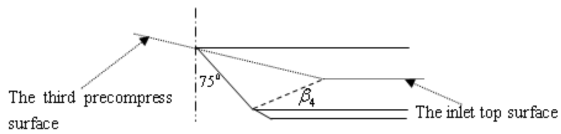

Fig. 5 Hypersonic inlet design

Control surface design

The control surface used in this paper is dropped from X-43A.

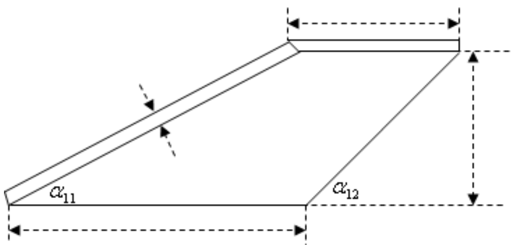

Fig.6 Control Surface Design

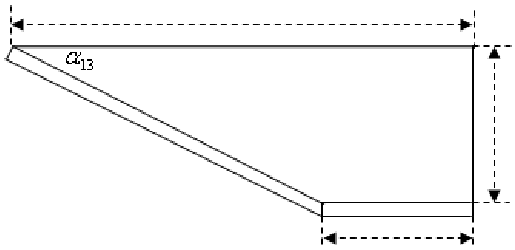

Fig.7 Control Surface Design

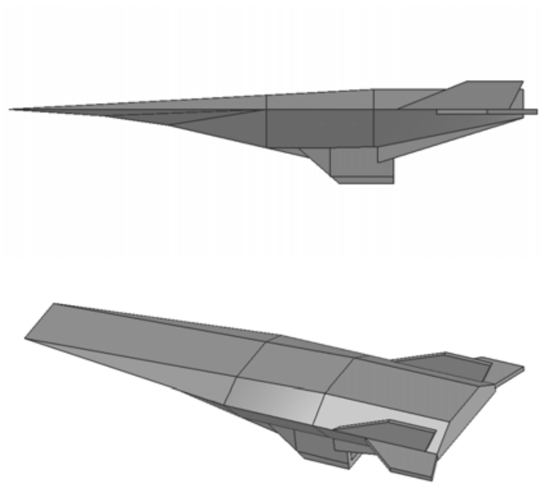

Fig.8 Waverider Vehicle Configuration

2 SIMULATION

The model is a direct simulation Monte Carlo method derived from the Larsen-Borgnakke method for the analysis of inelastic collisions. Tests performed in conditions near space at an altitude of 30km-70km show significant effects of rarefied gases on the evaluation of the hypersonic aerodynamic characteristics.

The effects of individual vehicle components on hypersonic configurations are examined by the DSMC simulation result. the controllability of each of the fully integrated vehicles and the effectiveness of the control surface design are also evaluated.

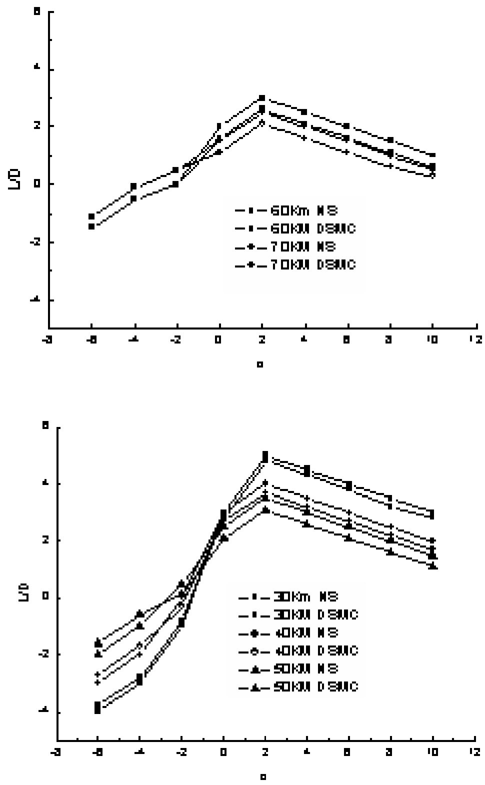

Fig.8 L/D characteristics Derived by DSMC and NS

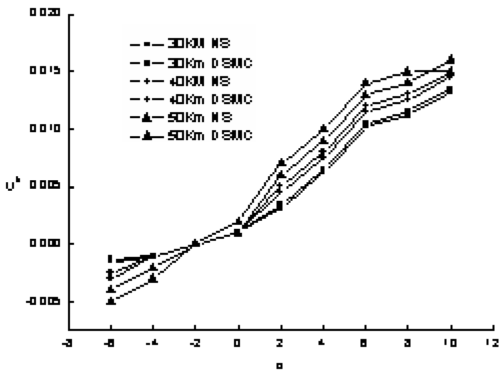

Fig.9 C_m characteristics Derived by DSMC and NS

3 Conclusion

The direct simulation Monte Carlo （DSMC) method and its models are studied. DSMC program is developed to investigate and analyze the aerodynamic and of hypersonic waverider vehicles in near space. With the structured body-fitted grids, the movement of simulate molecular is traced and the collision mol ecules is selected. Based on the structured grids, the molecules' tracing and locating method, which is cal led grid face vertical vector tracing method, is devel oped. Using this method, the molecular movement, mole cularindexing and the collision between mole cules and body surface are finished in a cycle. More over, molecules are located by computing the dot pro duct of the six grid faces vertical vector. With the me thod, flows in transitional region around waverider are simulated in near space rigon. The aerodynamic and flow characteristics are analyzed. By comparing the present results with the reference results and exp erimental data, it is proved that the method developed in this paper is reliable. The analysis of simulation res ults confirms the validity of the suggested scheme and tecniques.

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