11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

OPTIMIZATION AND ANALYSIS FOR COMPRESSION SHAPE OF WAVERIDERS WITH SHARP/BLUNT LEADING EDGES

Kai Cui*, Guangli Li, and Yao Xiao

State Key Laboratory of High Temperature Gas Dynamics, Institute of Mechanics, Chinese Academy of Sciences, Beijing 100190, China
*Corresponding author: kcui@imech.ac.cn

Key Words: *Waverider, Shape Optimization, Differential Evolution Methods, Design of Experiments, Computational Fluid Dynamics*

Waverider [1] configuration is a type of hypersonic lifting body. When flying at its design Mach number, the entire bow shock is attached to the leading edge (LE) of the body, so there is no flow spillage from the lower surface to the upper surface accordingly. As a result, the high pressure behind the shock wave leads to a considerably higher lift-to-drag ratio (L/D) than that for a generic shape. Because the vehicle appears to be riding on top of the attached shock wave when flying at its design point, hence it is dubbed the “waverider”.

Various optimization studies had been carried out to pursue a high L/D. Typically, Bowcutt [2] obtained a series of viscous optimized waveriders derived from conical flow fields by using the simplex method. Corda [3] followed his work and extended the original flow fields to axisymmetric power-law shape derived flow fields. Hitherto, the optimization work of waveriders were all taken the LE as the design variable as far as we know.

A waverider can be derived from any flow field with shock waves theoretically. For an example, a method based on the computational fluid dynamics (CFD) is presented by Cui et al [4] for a flexible waverider’s design, where the generating bodies of this method could be any cones. It is easy to imagine that we can design various waveriders with an identical LE and different compression (lower) surfaces. Naturally, the shape optimization of the compression surface motivates our study.

A key point of this work is how to parameterized the lower surface, which is cannot be expressed by any explicit formulation, but is designed by solving streamline equations. In this paper, an incremental-based parameterization method is used to deal with this problem. The main idea of this method is to divide the lower surface into two parts, i.e. the baseline and the increment. The baseline is generated by using common methods and is fixed. During optimization only the increment is taken as the design variable. Therefore, the complex surface can be described by only a few parameters.

Based on the above parameterization method, a series of shape optimization studies for waveriders with sharp and blunt LEs were carried out in this paper. The differential evolution method combined with a Euler equation's solver are employed for sharp LE waveriders. While for blunt LE waveriders, a design of experiments method and a Navier-Stokes equation's solver are adopted. The results show that the L/D gains significantly improvement after optimization(more than 20 percent). However, both the lift and the volume decrease apparently with the increase of the L/D. Therefore, a multi-objective optimization for the shape of compression should be carried on under the constrains of the lift-weight matching, the volume, the thrust-drag matching in future actual design work.

REFERENCES

[1] T.R.F. Nonweiler, Delta wings of shapes amenable to exact shock-wave theory, *Journal of the Royal Aeronautical Society*, Vol. 67, pp. 39-40,1963

[2] K.G.Bowcutt, J.D.Anderson, and D.Capriotti, Viscous optimized hypersonic waveriders, 1987, AIAA-87-0272

[3] S.Corda and J.D. Anderson, Viscous optimized hypersonic waveriders designed from axisymmertirc flow fields, 1988, AIAA-88-0396

[4] K.Cui, G.W.Yang, Waverider configurations derived from general conical flowfields, *Acta Mechanica Sinica*, Vol. 23, No.3, pp. 247-255, 2007