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Computational Grid-Fin Analysis

Nirmal Kumar Balaguru*
*Department of Aerospace,
University of Petroleum and Energy Studies,
Dehradun

Karthik Sundarraj
Technical Manager – CFD
ARK INFOSOLUTIONS PVT. LTD-
Bangalore, India

***Abstract* - The purpose behind this paper is to understand the flow physics associated with grid-fin. The two type of grid fin that is plate type and diamond type is considered. Analysis is done for Mach number ranging from 1.1 to 3.The physics associated with the grid fin flow is understood by classifying the flow into five regimes, namely, single plate regime, periodic plate regime, separated flow regime, cusped shock regime and single body regime. The lift curve exhibits high non-linearity for lower free stream Mach numbers close to sonic conditions and for higher Mach numbers exhibits a bucket associated with the stalling and subsequent un-stalling of fins in the separated. . When the angle of attack is varied from 0 to 24, for particular Mach number 2, the shock waves which is formed in the leading edge will interact with the expansion fan that is formed in trailing edge and the way these both interacts leads to the flow regimes that are mentioned above**

Keywords: Grid-fin, Expansion fan, Shock waves, Lift, Coefficient of lift (C_L), Coefficient of Drag (C_D)

II INTRODUCTION

Grid-fins are the elements which are used to control the trajectory of a missile. The main advantage of grid-fin is it has small chord length i.e. it reduces the power and size of actuators which produces torque to turn the grid-fin so that the aerodynamic body changes its trajectory.Though there have been several studies in the past, both experimental and computational, which have dealt with the aerodynamics of the grid-fins, no serious attempts have been made to understand the flow physics associated with the grid-fins. The works done earlier predominantly relates to grid-fin performance with the fore body and hence the pooled effect of all grid-fin collectively with fore body is presented, but they all divert from seizing the effect of individual fins. The performance of individual grid-fins should be understood with the non-linearities that they exhibit, else designing the missile will be perilous. Therefore in this work we have attempted to understand the flow physics using isolated grid-fin configurations. [1][2]

The two type of grid-fins namely, plate and diamond shape grid-fin is analysed in various Mach number i.e. from 1.1 to 3. The lift and drag curves for both cases are compared

III CONFIGURATIONS

In basic objective to understand the flow physics which is surrounding the single grid-fin a series of five plates had been taken for our convenience and the flow physics of a single plate and the effect a plate create over the other plate can be studied. Each plate comprises of five centimetres long with the idealized thickness of 0.1 centimetre. The both ends i.e. the leading and trailing edge of the plates has a curve end of radius of 0.05 centimetres. And, another 5 plates of diamond shape with length of 5 centimetres and thickness of 0.5 centimetres are taken as per figure.

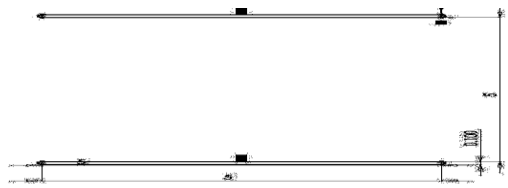


Figure 1: Plate grid-fin

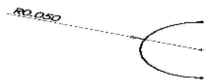


Figure 2: View of curved View

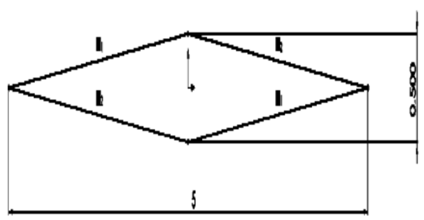


Figure 3: Diamond grid-fin

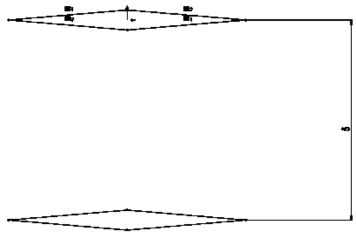


Figure 4: View of two diamond grid-fin

All dimensions are in mm

IV ISOLATED PLATEAND DIAMOND GRID-FIN CONFIGURATIONS

An idealized grid is made on the entire domain. The grid independence study has been done and the following grid has been selected. The parameters for grid 1 is used to transonic conditions while grid 2 is preferred for higher Mach number relation

Parameter	Grid 1	Grid 2
Field Nodes	2,90,300	2,35,260
Boundary layer 1st cell	2.5e-6	2.5e-6
Growth rate	1.1	1.1
Upstream boundary domain extent	4C	0.5C
Downstream boundary extent	2C	4C
Normal axis domain extent	3C	2C

Table 1: Meshing parameters

The boundary layer is made and mesh as such a resolution so that the flow physics around the grid-fin is captured efficiently.A different shape of grid-fin is taken and it is meshed with the parameters (refer grid information) and analysed with boundary conditions in ANSYS-FLUENT solver with viscous models as spallartallamaras, pressure and temperature conditions that are mentioned at 3km altitude in density based solver, it is considered as steady state time condition under implicit formulation, Least square cell based gradient.

RESULTS

Since there is an obstruction due to geometry and hence the geometry is in blunt shape it is sure the bow shock will be formed in front and when the flow crosses the geometry there will be an expansion fan created. The interaction between the shock and the expansion fan gives path to five different regimes which are discussed bellow

a. SINGLE PLATE REGIME

In this regime the plate kept at equal intervals does not experience the presence of another plate. This is obtained at Mach 2.0 in angle of attack from 0, 4 and 8. The detached shock which is formed in leading edge of plate and the expansion fan is formed in the trailing edge of the plate. The shock which is formed in the front hints the expansion fan. These waves hits together and the shear layer, formed at trailing edge of the plate. That is the shock from the leading edge of previous plate interacts with expansion wave of next plate past the geometry.

b. PERIODIC PLATE REGIME

In this flow regime, except the top and bottom plate behave as periodic plate. In this regime the shock which is formed in leading edge hints the bottom of the plate. The pressure across the shock always increases and so the plate will be having the higher pressure at the bottom side of the plate when compared to the pressure present at the top portion of the plate. For a proper high lift the upper portion of plate should have the higher pressure when compared to lower portion of plate. So lift is reduced in this flow regime. The place where the bow shock impinges the bottom surface of the plate occurs flow separation flow separation. For Mach 2 it is visible for incidences 12 to 17

c. SEPARATED FLOW REGIME

If the angle of incidence is increased further the periodic plate regime comes to an end due to formation of bubbles over the upper surface of the plates so that the pressure relaxation factor will not be present due to formation of bubble. Once bubble is obtained in one plate, further increasing of angle of incidence will lead to formation of separation bubble on all plates present in the domain. Here, due to formation of bubble the drag which is obtained also falls down showed in figure 5 and figure 6.For Mach 2 it is visible for incidences 17.75 to 22

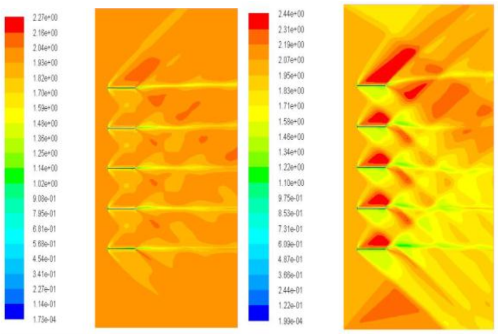
d. CUSPED SHOCK REGIME

In this flow regime the cusped shock is formed before the leading edge. Till the start of this regime the flow regime has a significant result in the top surface of the flow regime. Now this is moved to bottom surface of the plate where the normal shock coming towards the front edge results or lead to formation of cusped shock at the end. This is observed at both Mach 1.5 (incidence 8 to 14) and 2 (incidence 24).

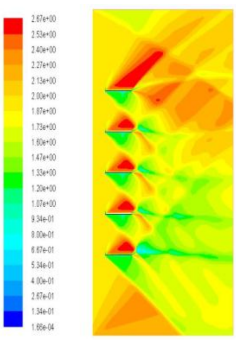
e. SINGLE PLATE REGIME

When the angle of incidence is further increased, only the single bow shock is formed. This happens because the entire five different plates kept at equal intervals behave as a single body. This happens only in lower Mach numbers ranging from Mach number of 1.1 and 1.5.

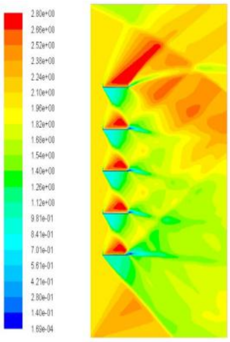
PLATE GRID-FIN



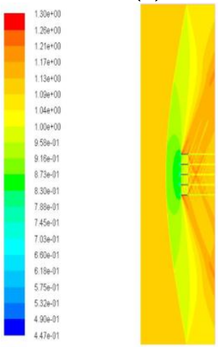
(a) (b)



(c)



(d)



(e)

COMPARISION OF LIFT AND DRAG CURVES IN PLATE AND DIAMOND GRID FIN

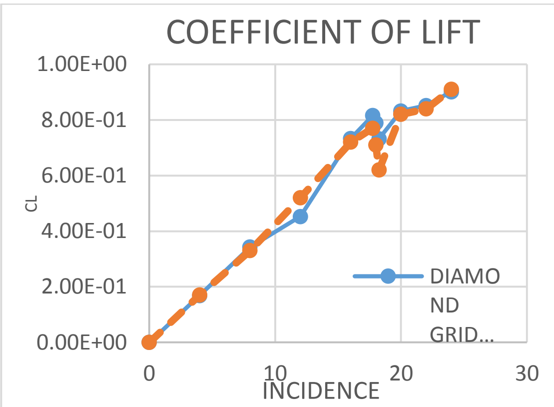


Fig 5: C_L Vs Incidence

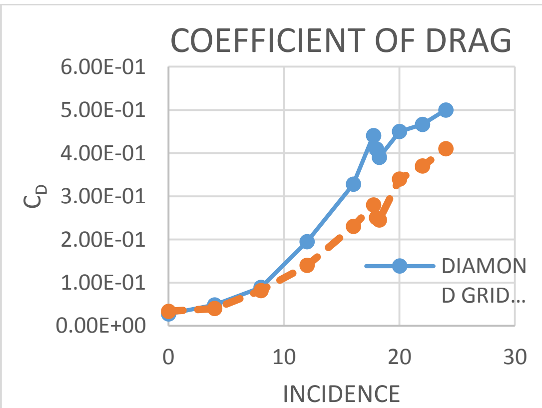


Fig 6: C_D Vs Incidence

V CONCLUSION

- The bucket formation in the lift and drag curve is detected at higher incidences for higher Mach numbers.
- The flow regimes is identified at lower incidences at lower Mach numbers compared to higher mach numbers.
- Due to higher degree of non-linearity, it is difficult to identify flow regimes at lower angle of attack and in single body flow regime and cusped shock flow regime the plates feel subsonic flow and these flow regimes may not be significant since they are absent in practical flows.

In Mach number 2 the plate and diamond grid-fins are analysed and compared with the completed Mach number of 1.1, 1.5, 2, 2.5, and 3. The flow physics is understood, the flow regimes are identified and bucket formation in lift and drag curves are identified.

VI REFERENCES

[1] CFD Simulation of the Grid Fin Flows by Ravindra K, Nikhil V. Shende and N. Balakrishnan Submitted to 31st AIAA Applied Aerodynamics Conference, 24–27 June 2013, San Diego, California

[2] Aerodynamic Characteristics of G16 Grid Fin Configuration at Subsonic and Supersonic Speeds by Prashanth H S1, Prof. K S Ravi2, Dr G B Krishnappa3International Journal of Engineering Research and General ScienceVolume 2, Issue 5, August – September 2014.