EFFECT OF MAGNUS FORCE ON SPIN STABILIZED MISSILE IN NORMAL CROSSWIND CONDITIONS

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ABSTRACT

When the missile is stabilized by its spin and geometry we considered for the missile is almost cylinder, which produces Magnus force when it experiences crosswind. The produced Magnus force create disturbances in its flight path or Magnus force can be used for Maneuvering purpose by finding the stable condition of the missile. This paper determines the Number of Rotation for which the Magnus force is Zero under normal crosswind condition.

KEYWORDS: Spin Stabilization, Magnus Force on Spinning Missile, Crosswind Conditions

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INTRODUCTION

Cylindrical geometry missile is considered in this paper. The dimensions of the missile are geometrically similar to K4 missile. Missile is spinning about longitudinal axis and we have assumed crosswind direction perpendicular to longitudinal axis as shown in Figure 1. In real life, flying object is moving. So we use term called “Flight velocity”. But in Aerodynamics, object is stationary and fluid is moving. So we use term called “Freestream velocity”. Freestream velocity used in this paper is in subsonic range.

If the cylindrical geometry is spinning in crosswind stream, Magnus force will be generated perpendicular to crosswind direction and freestream velocity. That is crosswind moves along Z axis, missile is spinning about X axis and Magnus force generated along Y axis

Figure 1: Normal Crosswind and Free Stream Direction with respect to Missile in XYZ Coordinate System

Figure 2: Magnus force generated along Y axis
(Depends on Clockwise & Anticlockwise rotation, the Magnus force direction depends)

Due to the spinning of the missile in the normal crosswind stream, Magnus force is generated perpendicular to flight velocity which create disturbance in flight path. If we found the stable condition of missile spinning in crosswind conditions, we can use this Magnus force for Maneuvering. This paper identify the amount of spin of missile for which the Magnus force is Zero.

METHODS

We are analyzing the spinning object in two perpendicular different linear velocity stream. That is freestream velocity is perpendicular to crosswind velocity. Freestream velocity used in this paper are 100 m/s, 200 m/s and 300 m/s. Crosswind velocity used in this paper 1 m/s, 2 m/s, 3 m/s, up to 10 m/s. our goal is to find the amount of spin of the missile for which the Magnus force is zero. So we set a constant freestream velocity and crosswind velocity stream over a missile and giving different amount of spin of the missile which gives set of different Magnus force. Example setting freestream velocity as 100 m/s and crosswind velocity as 1 m/s. Spin of the missile as 30 RPM, 60 RPM, etc. For 30 RPM, we will get one force value perpendicular to freestream direction and crosswind direction say F1. For 60 RPM, we will get one force value perpendicular to freestream direction and crosswind direction say F2 and so on. We found force values F1, F2, F3, etc. for RPM 30,60,90, etc. If the value of force either changes from positive value to negative value or vice versa, we can stop the analysis for 100 m/s freestream velocity and crosswind velocity 1 m/s. F1, F2, F3 are Magnus force for different RPM of Missile. Draw a graph "RPM of missile vs Magnus force" and find RPM of force for which Magnus force is zero. Repeat the whole process for remaining freestream and normal crosswind velocity.

Design

Software Used: CATIA V5 R20

Figure 3: Three View Missile Dimension

Figure 4: Domain Dimension

Figure 5: Missile with Domain in Section View

Introduction to CFD

Meshing is done in ICEM CFD. ANSYS CFX will be appropriate for rotating component since our missile is spinning.

1. Type: Flow Analysis
2. Software Package : ANSYS 16.1
 - a. Meshing : ICEM-CFD 16.1
 - b. Pre-processing : CFX-Pre 16.1
 - c. Solver : CFX-Solver 16.1
 - d. Post-Processing : CFD-Post 16.1

a) Analyze: Domain Creation and Meshing in ICEM - CFD:

Figure 6: Meshing of Missile

a) Boundary Conditions

- Freestream Velocity: 100m/s, 200m/s & 300m/s along X axis
- Normal Crosswind velocity: 1 to 10m/s along Z axis

- Atmosphere: Opening Pressure at 101325 Pa along Y axis

Figure 7: Missile with Complete Domain and Boundary Condition

RESULTS

1. Freestream Velocity: 300m/s: Normal Crosswind Velocity: 1-10m/s

Graph 1: RPM of missile vs Magnus Force at Freestream Velocity 300m/s with different Normal Crosswind Velocity

Note: Negative sign in the RPM denotes Anti-clockwise rotation. Magnus Force is non-zero at Zero RPM of missile due to interaction of Freestream wind and Normal Crosswind on Missile.

By identifying the RPM for which Magnus force is Zero and plot a graph for Normal Cross wind velocity and RPM

Graph 2: RPM of Missile (for which Magnus force is zero) with respect to different Normal Crosswind Velocity at Freestream Velocity 300 m/s

2. Freestream Velocity: 200m/s: Normal Crosswind Velocity: 1-10m/s

Graph 3: RPM of Missile vs Magnus Force at Freestream Velocity 200m/s with different Normal Crosswind Velocity

Note: Negative sign in the RPM denotes Anti-clockwise rotation. Magnus Force is non-zero at Zero RPM of missile due to interaction of Freestream wind and Normal Crosswind on Missile.

By identifying the RPM for which Magnus force is Zero and plot a graph for Normal Cross wind velocity and RPM

Graph 4: RPM of Missile (for which Magnus force is zero) with respect to different Normal Crosswind Velocity at Freestream Velocity 200 m/s

3. Freestream Velocity: 100m/s: Normal Crosswind Velocity: 1-10m/s

Graph 5: RPM of missile vs Magnus force at freestream velocity 100m/s with different normal crosswind velocity

Note: Negative sign in the RPM denotes Anti-clockwise rotation. Magnus Force is non-zero at Zero RPM of missile due to interaction of Freestream wind and Normal Crosswind on Missile.

By identifying the RPM for which Magnus force is Zero and plot a graph for Normal Cross wind velocity and RPM

Graph 6: RPM of missile (for which Magnus force is zero) with respect to different normal crosswind velocity at freestream velocity 100 m/s

4. Comparison of Different Freestream Velocity

Graph 7: Comparison of zero Magnus force RPM curve for different freestream velocity

DISCUSSIONS

- The point in the graph “RPM of missile (for which Magnus force is zero) with respect to different normal crosswind velocity at freestream velocity 300 m/s (i.e. Graph 2)” taken from crosswind curves crossing X axis in Graph “RPM of missile vs Magnus force at freestream velocity 300m/s (i.e. Graph 1)”.
- The point in the graph “RPM of missile (for which Magnus force is zero) with respect to different normal crosswind velocity at freestream velocity 200 m/s (i.e. Graph 4)” taken from crosswind curves crossing X axis in Graph “RPM of missile vs Magnus force at freestream velocity 200m/s (i.e. Graph 3)”.
- The point in the graph “RPM of missile (for which Magnus force is zero) with respect to different normal crosswind velocity at freestream velocity 100 m/s (i.e. Graph 6)” taken from crosswind curves crossing X axis in Graph “RPM of missile vs Magnus force at freestream velocity 100m/s (i.e. Graph 5)”.

- Graph 2, Graph 4 & Graph 6 shows amount of spin required for missile which is not affected by Magnus force with respect to different freestream velocity and crosswind velocity.
- We can use the Magnus force for missile maneuvering purpose by setting the values of Graph 2, Graph 4 & Graph 6 as reference
- Since we considered normal crosswind velocity as 1 to 10 m/s, which ratio with freestream velocity (i.e. 100m/s) is sufficiently larger than freestream velocity 200m/s & 300m/s.
- The Normal Crosswind velocity vs RPM graph is almost linear for 200m/s & 300m/s. But at 100m/s, Normal Crosswind velocity vs RPM graph is not linear due to High Crosswind to Freestream velocity ratio.

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