Applicability of Canister For Barraging Missiles

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Abstract

Computational Fluid Dynamics analysis has been carried out for the canister with a gas generator in it. The objective of this project is to estimate the total energy loss inside a canister, which includes the heat and gas dynamics losses. The output flow properties like total pressure and static pressure variations, maximum velocity and mass flow rate through the gas generator nozzle are analysed. Finite volume method technique is used for solving the solution. CATIA model has been imported to the computational software ANSYS CFX where non-conformal meshing is been created and results have been analysed.

Keywords: Canister; Missile Launching; CFD.

Introduction

The missile ejection system comprising: A Canister formed as a cylindrical shell, a partition wall protruding from an inner wall of the canister so as to divide the canister into a first chamber for housing a missile there within and a second chamber, and having at least one hole there through for allowing the flowing of gas through the partition wall. Canister is cylindrical container for holding, carrying, storing and launching of missile, usually specified object or substance. It also has a gas generator secured to the partition wall in the second chamber so that a gas outlet thereof faces in an opposite direction from the first chamber, and an obturator including a sealing plate formed with a concave surface toward a fore-end of the missile for enclosing a tail end of the missile. A radially extending skirt plate extended from the circumference of the sealing plate to the inner wall of the canister is found which is inclined toward the fore-end of the missile for covering the space between the missile and the inner canister, wherein the missile is propelled by the pressure of the gas discharged out of the gas generator from the second chamber to the first chamber through the hole, being pressurized by the flowing gas in the first chamber, pushing upon the obturator.

Thereby, the system is able to effectively release a missile from a canister by a gas generator without using a missile propulsion engine, thereby fundamentally preventing the damage of ground equipment or peripheral missiles. If inert gases such as nitrogen are used, there won't be any further combustion inside the canister dome. Instead if air is used, there will be further combustion, which results in increased energy loss during canister LV launching.

Canisterised multistage long range launch vehicle has the advantages of short launch preparation time, easy storage, and easy transportation. Canisterised LV system will be cold launched using gas generator mounted at the aft end dome of canister. The canister in vertical condition LV is propelled out by the pressure generated by gas generator and once LV is completely out of canister Stage-I ignition will started at specified height from the ground.

Literature Survey

Rhett Shaw and Mark Gillcrist, (2003) presented a paper, describing a NASTRAN finite element near-miss shock response simulation of a Vertical Launch Anti-submarine Rocket (VLA) missile carrying a Mk 54 torpedo for which the level shock conditions aboard ship was predicted. The numerical simulation represents an encanistered Mk 54 VLA missile in a launcher cell subjected to "qualification level" shock. The finite element representation models the torpedo, airframe, rocket motor, canister, canister adaptor. Il-Soo Kim et.al.(2006), studied on lateral support device system of a canister-launched missile of the present invention is provided for eliminating the clearances between missile and the canister in 4 places by 90 degrees interval, and therefore no relative movement occurs between the missile and the canister. Rajeev (2009), studied about Canisterised Launch Simulation. This paper discusses the finite element analysis based numerical simulation of Canisterised Launch from an Integrated Mechanical System. Jon J. Yagla et.al. researched about Launch Dynamics Environment of a Water Piercing Missile Launcher. The discussion is as: the Water Piercing Missile Launcher (WPML) is based on the Concentric Canister Launcher (CCL). The launcher
uses the gas jet emitted from the CCL to pierce the ambient water above a submarine or other submerged platform. Tarak Nath De et. al. discussed about Configuration Design of Spring Loaded Detachable Canister-Launch Vehicle Interface for Multistage long Launch Vehicle. Canisterised multistage long range launch vehicle has the advantages of short launch preparation time, easy storage, easy transportation and camouflaging. Yongquan Liu and Anmin Xi (2013) studied about the interior trajectory simulation of the canister launched missiles has been developed with the help of FLUENT. One of the special features of this simulation is the method by which the coupled three phase problem is reduced to solve the fluid equations only.

**Design of the Canister Model**

The design of the canister model has been done by using the CATIA V5R19 software. CATIA mechanical design solutions provide tools to help you implement a sophisticated standard based architecture. This enables collaborative digital mock-ups and hybrid designs.

**Dimensions of Canister**

The dimensions of the canister used for the analysis is,

| Sl.No. | Details                             | Dimensions (mm) |
|--------|-------------------------------------|-----------------|
| 1      | Height                             | 9.042D          |
| 2      | Internal Diameter                  | D               |
| 3      | Thickness of wall                  | 0.0081D         |
| 4      | Radius of the lower section curvature | 0.75D         |
| 5      | Thickness of lower section curvature | 0.0071D       |
| 6      | Height of the canister dome assembly | 0.75D         |

| Sl.No | Details                              | Dimensions |
|-------|--------------------------------------|------------|
| 1     | Height of Gas Generator              | 0.44D      |
| 2     | Diameter of Gas Generator            | 0.31D      |
| 3     | Nozzle Throat Diameter               | 0.043D     |
| 4     | Divergent area ratio                 | 1.5        |
| 5     | Divergent half angle                 | 14 deg     |

| Sl.No | Details                              | Dimensions (mm) |
|-------|--------------------------------------|-----------------|
| 1     | Diameter of the upper plate of Obturator | 0.99D         |
| 2     | Diameter of the lower plate of Obturator | 0.57D         |
| 3     | Thickness of Plates                  | 0.0095D        |
| 4     | Height of Obturator                  | 0.107D         |

**Grid Generation and Computation**

The grid designates the cells or elements on which the flow is solved. The grid has a significant impact on the rate of convergence (or even lack of convergence), solution accuracy, and CPU time required. The importance of mesh quality for good solutions are grid density, adjacent cell length/volume ratios, skewness, tetrahedral vs. hexagonal grid, boundary layer mesh, and mesh refinement through adaption. Since analytical solution is available only in simplest of cases, numerical techniques are required; thus a grid across flow domain needs to be defined. Unknowns are determined at each grid point. This concept may be extended into time domain. The CATIA model was imported to Ansys CFX where the grid has been generated. Non Conformal Mesh is used for the parametric study of complex geometries. Nonconformal capability allows you to replace portion of mesh being changed. Start from 3D boundary mesh or volume mesh. Add or replace certain parts of mesh. Remesh volume if necessary.

**Table 4. Mesh Information for Canister.**

|       | Nodes | Elements |
|-------|-------|----------|
| Nodes | 158073| 835768   |

For solving the solution k-ε turbulence model is been used. Hence, two other equations are been used for the solution extraction.

The Boundary conditions, Domain Physic and the inlet flow properties are tabulated below.

The Mass flow rate given as the boundary condition is to be varied.
at each 0.2 sec interval of time. The variation of inlet mass flow rate is shown in Table 7.

![Figure 3. Meshed canister.](image)

Table 5. Mesh information for gas generator nozzle.

| Nodes   | 64819 |
|---------|-------|
| Elements| 287386|

![Figure 4. Meshed Nozzle.](image)

Table 6. Boundary Conditions for CFX.

| INLET | Flow Direction | Normal to Boundary Condition |
|-------|----------------|------------------------------|
| Flow Regime | Subsonic |
| Mass And Momentum | Mass Flow Rate |
| Mass Flow Rate | 18.00 kg s^-1 (at 0sec) |

| OUTLET | Mass And Momentum | Static Pressure |
|--------|-------------------|-----------------|
| Relative Pressure | 1.00 atm |

| WALL | Mass And Momentum | No Slip Wall |
| Wall Roughness | Smooth Wall |

Table 7. Domain Physics for CFX.

| Type          | Fluid          |
|---------------|----------------|
| Morphology    | Continuous Fluid |
| Buoyancy Model| Non Buoyant    |
| Domain Motion | Stationary     |
| Reference Pressure | 1.00 atm   |
| Fluid Temperature | 25 °C         |
| Turbulence Model | k epsilon     |
| Turbulent Wall Functions | Scalable |

Table 8. Flow properties at inlet.

| TIME (Sec) | MASS FLOW RATE (Kg/Sec) | PRESSURE (ksc) |
|------------|-------------------------|----------------|
| 0          | 18                      | 40             |
| 0.2        | 24                      | 55             |
| 0.4        | 30                      | 70             |
| 0.6        | 38                      | 90             |
| 0.8        | 50                      | 110            |
| 1          | 56                      | 130            |
| 1.2        | 70                      | 160            |
| 1.4        | 36                      | 80             |
| 1.6        | 13                      | 22             |
| 1.8        | 8                       | 12             |
| 2          | 7                       | 10             |
| 2.2        | 7                       | 10             |

The analysis is done by considering the output static pressure from the analysis for each time step as the outlet boundary condition for the next time step.

Results and Discussion

ANSYS CFX 14 has been used to study the flow properties through the nozzle configuration.

Steady State Analysis

![Figure 5. Static pressure variation during 1st timestep.](image)

The outlet parameters of the flow through the gas generator nozzle are obtained from analysis using Ansys CFX. Figure 5 shows the variation of static pressure during the first time step (0 sec) of start-up. In a convergent-divergent nozzle, the pressure will be reducing from the inlet to the outlet.
The variation of Mach number during the first time step (0 sec) of start-up is shown in Figure 6 and the variation of velocity at 0 sec of start-up is shown in Figure 7. In both the cases the trend is the same. In a convergent divergent flow with subsonic inlet flow, the velocity will be increasing throughout the nozzle from inlet to outlet. Hence an increased velocity is obtained in the outlet of the gas generator nozzle.

The variation of Mach number and velocity are shown in the Figure 8 and Figure 9 respectively at 1.2 seconds from start up. This is the time at which the mass flow rate and the pressure at the inlet of the gas generator nozzle become maximum. The variations of static pressure and total pressure through the nozzle at 1.2 seconds from start-up are shown in Figure 10 and Figure 11 respectively. The static and total pressure are also become the peak at 1.2 seconds along with the inlet parameters and then it'll start reducing afterwards till the end of the process.
The outlet parameters of the gas generator nozzle are varying from the first time step to the last time step (i.e. from 0sec to 2.2 sec). The outlet properties of the nozzle depend not only on the inlet parameters of the nozzle but also affect the outlet properties of the previous time step. During this analysis, the outlet boundary condition for each time step is obtained from the analysis of the previous time step. Thus, the analysis is done for 13 time steps from start up till the end of the process with a time interval of 0.2 seconds. The outlet properties are obtained for each analysis and these properties are varying at each time step.

Figure 12 shows the outlet velocity through the nozzle at each time step. It is obtained that the velocity is decreasing from 1.2 seconds of start-up. This is because of the decrease in mass flow rate at the inlet from 1.2 seconds. The outlet Mach number through the nozzle at each time step is also having the same trend of variation, which is shown in the Figure 13.

The static pressure at the outlet of the nozzle and the total pressure at the outlet of the nozzle are having a same trend of variation with respect to time, that are shown in Figure 14 and Figure 15. There is an increase in pressure at the outlet of the nozzle with respect to time as the mass flow rate is increasing. After 1.2 seconds, it starts decreasing till the end of 2.2 seconds.

**Conclusion**

CFD computations were used to predict the flow field through the gas generator nozzle of the canister configuration. Computations were carried out for the nozzle to find out the outlet flow properties of the gas generator fluid and the results were obtained. It is found that the total and static pressure of the flow increases as the mass flow rate increases and vice versa. The trend of the curves seems similar.

The pressure, both static and total pressure of the flow is maximum at 1.2 seconds from the start-up of the gas generator and thereafter the pressure will reduce till 2 seconds. Then there will be a reduced pressure, which is constant till the end of 2.2 seconds.

The maximum static pressure obtained in the outlet of the gas generator nozzle is 615700Pa at 1.2 seconds from start up. The maximum total pressure obtained in the outlet of the gas generator nozzle is 1940000Pa at 1.2 seconds from start up.

The velocity and Mach number becomes peak at 0.8 seconds, and the maximum velocity obtained at the outlet is 422.3m/s and the maximum Mach number obtained at the outlet is 1.866. This maximum Mach number obtained is matching with the theoretical Mach number for the nozzle with area ratio 1.5.

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