Analysis of Collapsibility of Canister at High Speed in Ice Pellet Launcher Using ABAQUS/Explicit Software

Mohd Omer Farooq[1], Dr Mir Safiulla[2]

Post Graduate student, Department of Mechanical Engineering, Ghousia College of Engineering, Ramnagaram-571511, Karnataka, India[1]

Professor and Head, Research Centre, Department of Mechanical Engineering, Ghousia College of Engineering, Ramanagaram-571511, Karnataka, India[2]

ABSTRACT: Canister is a cylindrical shaped container, one end of which is open, in which bird specimen or ice pellets are loaded and fired in ice-pellet launcher system. The canister is propelled through the length of the gun barrel by means of compressed air and is arrested by canister arrester. High speed stainless canister with uniform and variable wall thickness is designed and then manufactured by the process of metal spinning in a spinning machine. For the canister to collapse without cracking, it is heat treated by annealing process. The base portion of the canister is hardened and the open end is made soft for it to collapse in desired fashion. The deformation of canister depends upon its length, internal diameter, wall thickness, shape of back face, hardness and ductility of the material. The study of collapsible characteristics of the canister is done using ABAQUS/Explicit software. For this 3D CAD modelling is done using CATIA V5 software and finite element meshing is done using HYPERMESH software. Collapsible characteristics of the canister are observed for uniform and variable wall thickness canisters, at different velocities. The result of this dynamic simulation which deals with the collapsibility characteristics of canister will be compared, at few specific velocities, for a few specific canister geometries, with the results of tests to be conducted on actual metallic canisters, in the canister launcher, now operational at the college.

KEYWORDS: Canister, Metal Spinning, ABAQUS, HYPERMESH, CATIA V5.

I. INTRODUCTION

Canister is the most critical Dynamic component in a bird launcher, which accelerates the birds or ice- pellet from rest to the desired launch velocity within a few milliseconds, the performance of the canister ultimately decides the correct velocity orientation, target accuracy, pitch and yaw positions of the birds at the time of impact of the engine that the safety of the rest article, either the static parts or the rotating parts of the engine are not compromised due to the cracking, tearing and the consequent release of the metallic debris of the canister. It keeps the ice-pellet/bird specimen centralized and coaxial with the launch barrel and provides necessary damping for withstanding the shock of launch impact with the arrestor lip, prevents the bird the rubbing with the internal surface of the gun barrel.

The canister is also expected to fold over least partially in the circumferential direction and thus serve to seat the high pressure air at the end of the gun barrel and prevent compressed air from gushing out into the target area and introduce secondary damage and minimize obscure visibility of the target components and thus help in obtaining clear high speed photography / videography.

The canister is a thin walled cylinder with either a flat back surface or a dome-shaped semi-hemispherical back end with the front end being open, for inserting the sabot and the bird specimen. The thickness of the cylindrical body as well as that of the back end could either be uniform or variable. The wall thickness at the front end and the rear end of the canister, wall thickness over on the cylindrical body are controlled during the deep drawing process. The strength of this canister, to withstand the "impact test shock", is imparted to the canister during the heat-treatment process. There

are major impact test programs in the country which are aimed at studying the penetration mechanisms, containment capability of "armor" materials, and bird strike capability of aero engine components. Many gas and compressed-air launchers are operating at Gas Turbine Research Establishment (GTRE), National Aerospace Laboratories (NAL), and Defence Metallurgical Research laboratory (DMRL) and Terminal Ballistic Research Laboratories (TBRL). These facilities do use canister of various sizes and materials. These are Over designed to ensure safety of the system but backed up by data on canister behaviour most of them work based on "Trial &Error" basis, with the attendant risk. Almost all defence selected agencies such as NASA, university Laboratories university of Dayton research institute (UDRI). For example aero engine manufactures such as General Electrical, Partt-Whitnery of USA Rolls Royce, UK, Snecina and France. Use highly optimized steel titanium canister for their impact programs. These are backed up by very detailed studies on materials, forming process, heat treatment, thickness and shape control on the canister.

Ice-Pellet Launcher is a Test Facility that launches ice pellets to simulate ice impact on aircraft and aero-engines. When ice pellets and slabs hit the aircraft, which fly at high speeds, including near-sonic speeds, they cause huge damage on to the body of the aircraft. This will also cause extensive damage to aero-engine parts, endangering the flight safety. The damage profile due to ice and even bird hits needs to be extensively analysed through simulation effort. More importantly they need to be experimentally studied by launching ice pellets on to aircraft/aero-engine parts at appropriate speeds and directions.

Compressed air is used to launch the ice pellets/bird specimen or any other projectile in this facility. A metallic canister is used to hold these ice pellets and is surrounded by a layer of gelatine. A high pressure air-tank, with 1500 litre capacity 10 bar operating pressure rating, is filled with compressed air by a 10-kW air-compressor. This stored compressed air is made to suddenly gush out by opening an electronically operated solenoid valve or a sophisticated rupture disc. The expanding compressed air accelerates the ice-pellets housed in the metallic canister. The "fired" canister would accelerate throughout the length of the gun barrel/launcher tube connected to front of the air receiver, gets arrested at the Canister Arrester junction at the end of the gun barrel and ejects the ice pellets/bird specimen at the desired speed. Before the arresting action of the canister the velocity of the projectile inside the gun-barrel would be measured using a laser operated velocity measuring system.
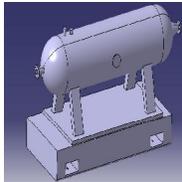
LAYOUT OF THE SYSTEM:
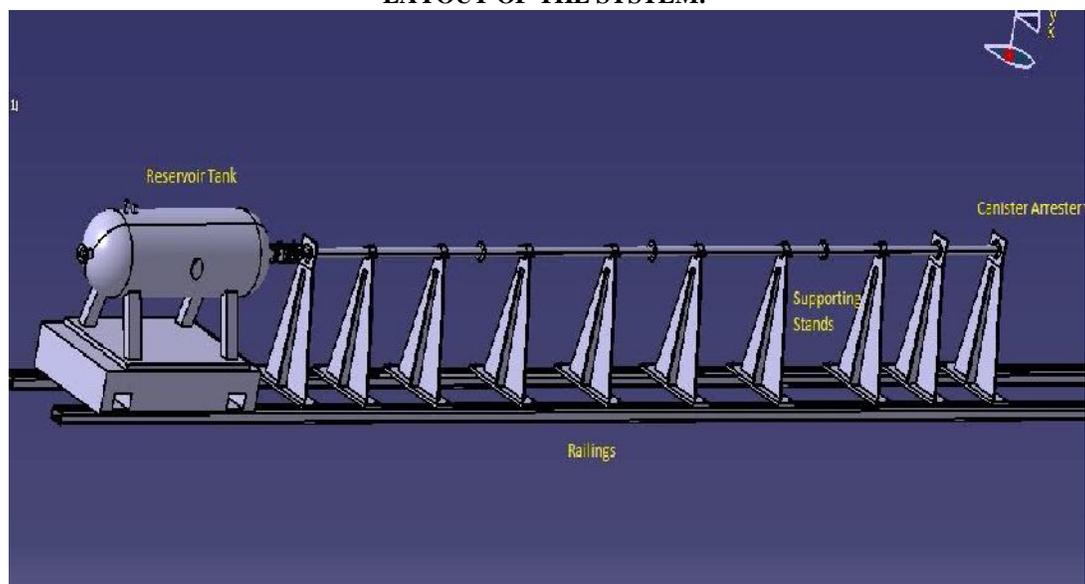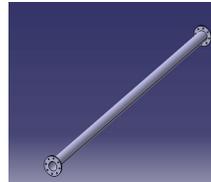
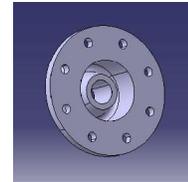**SUB ASSEMBLIES OF THE SYSTEM:**

| Reservoir tank | Solenoid valve | Canister | Gun barrel | Arrester |

II. LITERATURE SURVEY

At the 1996 London Meeting of the International Bird Strike Committee, an illustrated working paper was presented that provided brief details of all fatalities and destroyed aircraft due to bird strikes during the period 1912 to 1995. The paper was felt to be useful in drawing attention to the scale of the problem especially when dealing with those who know little about the subject or who are newly appointed to decision-making positions. Since the original paper was published, information has come to light on a number of previously unknown accidents as well as information on recent accident.

I have now believed that the number of fatal accidents has risen to 42 killing 231 people. In addition, the total of air craft destroyed is now 80.These is as follows:

- Airliners and Executive Jets -10 fatal accidents killing 164 and destroying 30 aircraft.
- Aero planes 5,700kg and below -27 fatal accidents 58 and destroying 42 aircraft.
- Helicopters -5 fatal accidents killing 9 people and destroying 8 helicopters. The paper provides briefs details on all above accidents together with some photographs. Analysis reveals that the threat (77% of accidents) to airliners and Executive Jets is engine ingestion, often due to flocks of gulls (Larus sp.). Aircraft of collision with birds of prey (Accipitriformes). These groups of aircraft mainly fly at heights where birds are most likely to be encountered. Some accidents are of pilots attempting to avoid birds.

Although not a major cause of fatalities, bird strikes are a serious safety and economics hazards. Bird strike accidents are events that can occur out –of –the –blue even at airports that may consider they have appropriate measures in place. The following figure shows Bird strike for plane & Helicopters:

Bird strike through nose cones of aero plane

Bird strike during flying of Helicopter

III. PROBLEM DEFINITION AND FINITE ELEMENT MODEL DEVELOPMENT

3.1 Problem definition:
Design, modelling of Canister and arrester for checking the collapsible characteristics are the main objective of the problem, which are as follows:

1. Design of Canister
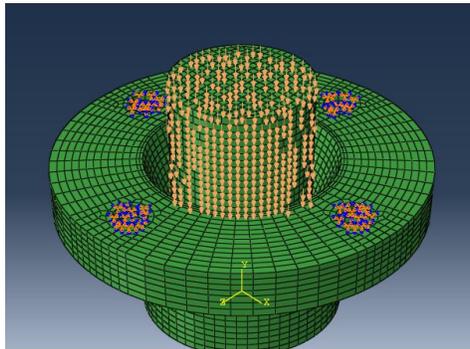2. Design of Arrester
3. Overall modelling and meshing

4. Analysis for Collapsibility

3.2 Dimensional representation of the problem:

Fig 1: Wire frame model of canister arrester

Fig 2: Cross sectional view of canister arrester with dimensions

Fig 3: Cross sectional view of canister

3.3 Material Specification:

Material	Aluminium 6061
Young's Modulus	67GPa
Poison's Ratio	0.33
Endurance limit	97MPa
Ultimate Tensile Strength	310MPa
Density	2.70g/cm^3

3.4 Meshed Model:

Fig: Overall Mesh

The above figure shows the model of canister and die. Canister is a cylindrical cup like structure, with an inner part empty. The thickness of the canister wall is 0.5mm. Die is made of hard material so that it can withstand with high stresses. Total of 1314 elements with1722 nodes are used for maintaining connectivity.

3.5 Boundary conditions:

Fig: Boundary conditions

The above Figure represents boundary conditions of the problem. Here bottom of die is fixed and the load on canister is applied with a uniform Velocity. So there is a need to check the collapsing condition of the problem. The problem is meshed with 8950 elements and 9131 nodes.

3.6 Assumptions:
1. Materials are assumed homogenous and isotropic up to yield point.
2. Nonlinear domain is applied after yield stress.
3. Contact elements are defined to obtain the solution, which employ iterative solvers for execution.
4. All Finite element approximations are applied during solving.
5. Bi linearity is assumed for nonlinear stress strain curve.

IV. RESULTS AND DISCUSSIONS

The analysis is done on canister with different shapes and arrester with different angles . The analysis results are as follows. The following cases are analysed.
- **Canister with flat bottom**
- **Canister with round bottom**

Case 1: Canister with flat bottom

The results are captured for stresses. The results are as follows.
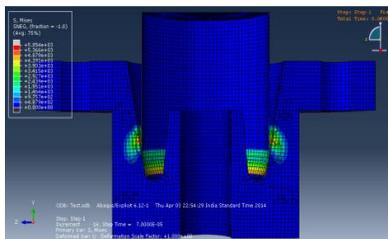
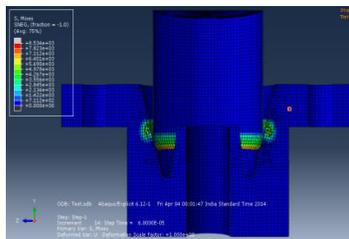Fig 4.1 Vonmises stress on canister and arrester with die angle 10°

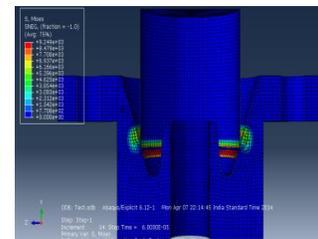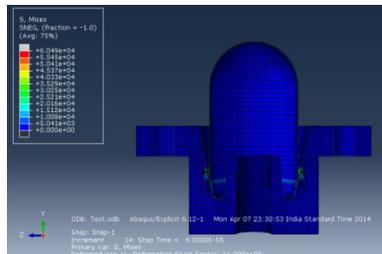Fig 4.2 Vonmises stress on canister and arrester with die angle 15°

Fig 4.3 Vonmises stress on canister and arrester with die angle 20°

Al 6061						
Flat Bottom						
Die Angle	**Von Mesis Stress(Mpa)**				**Step time (sec)**	
	Canister		Arrester		Point of contact	Peak point
	Point of contact	Peak point	Point of contact	Peak point		
10	**1.387e3**	3.887e3	8.129e2	**5.519e3**	1.319e-5	6e-5
15	**1.387e3**	3.887e3	8.129e2	**8.534e3**	1.319e-5	6e-5
20	**4.724e2**	**9.249e3**	2.16e2	7.604e3	1.319e-5	6e-5

Table 4.1 Vonmises stresses produced in canister with flat end and Arrester having different angles i.e., 10, 15 and 20^{0}

Case 2: Canister with Round bottom:

The results are captured for stresses. The results are as follows.

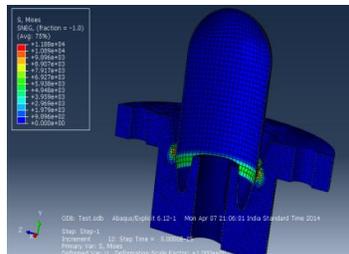Fig 4.4 Vonmises stress on canister and arrester with die angle 10º

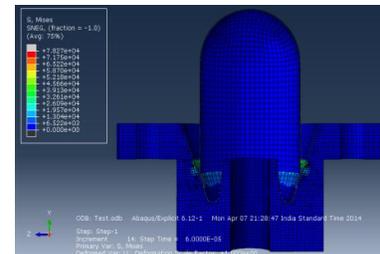Fig 4.5 Vonmises stress on canister and arrester with die angle 15º

Fig 4.6 Vonmises stress on canister and arrester with die angle 20º

Die Angle	**Vonmises Stress (Mpa)**				**Step time (sec)**	
	Canister		Arrester		Point of contact	Peak point
	Point of contact	Peak point	Point of contact	Peak point		
10	6.302e2	7.773e3	**1.473e3**	**6.049e4**	1.319e-5	6e-5
15	1.134e3	5.322e3	**3.182e3**	**1.188e4**	1.319e-5	6e-5
20	1.954e3	1.465e4	**4.0235e3**	**7.827e4**	1.723e-5	6e-5

Table 4.2 Vonmises stresses produced in canister with round end and Arrester having different angles i.e., 10, 15 and 20^{0}.

Bar Chart Showing the Comparison Between Different Die Angel of The Arrester:

Bar charts are used to compare between the results of same component of different parameter. Below is one such example which shows the comparison of arrester having different die angle with material, velocity and bottom shape of the canister keeping same.
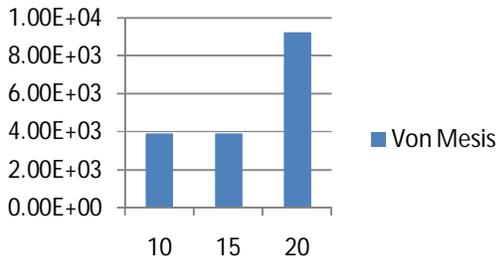
Stress Induced in the Canister

Fig 1: Stresses induced in canister with flat bottom.
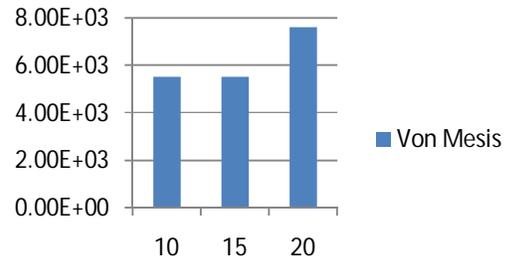
Stress Induced in the Arrester

Fig 2: Stresses induced in arrester using flat bottom canister.

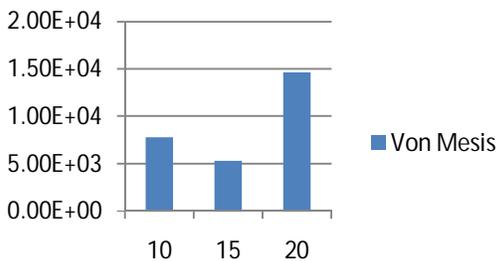## Stress Induced in the Canister

Fig 3: Stresses induced in canister with round bottom.

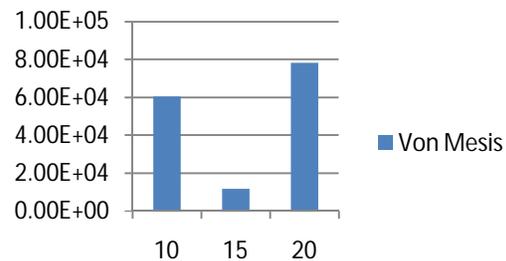## Stress Induced in the Arrester

Fig 4: Stresses induced in arrester using round bottom canister.

V. CONCLUSION AND FEATURE SCOPE

Canister analysis has been carried out to check the structural stability and collapsibility. The canister and die along with the guide pipe are modelled and analysed for the collapsibility and bending of canister under different conditions. Due to axis symmetric nature, axis symmetric approach is applied. Shell element used for representation of the problem. The geometry is split to ease map meshing. Bottom is constrained and top nodes are constrained for uniform movement. From the analysis and by visualising the above bar charts it is evident that, when a 20 degree die angle Canister Arrester comes in contact with high speed canister.

- It experiences high stress.
- Maximum internal energy.

- Maximum kinetic energy.
- Maximum strain energy.

➤ Initially the canister is made to hit the arrester having 10^0 angle. The stresses induced are less and we are getting circular shape at the bottom end of the canister and small fold ability at front face.

➤ For 15^0 angles the stresses are slightly more and the folding is further increased.

➤ As per the reviews we will observe that the bent on the canister is perfect due to its ductility

➤ To get the more deformation in the variable thickness canister we have to reduce thickness at the bottom end of the canister from 1.5mm to 1mm.

➤ If arrester die radius is lesser, then more bending area is occurring. Then bending of canister in required shape and size will more accurate.

➤ As per the test results the damage to the die is very less, hence we can prefer for experiment

Further Scope:

➤ Experiment should be carried on canister of varying thickness and simulation has to be done on same.

➤ Simulation can be carried out with non-linear properties of the material used to get accurate results.

➤ Actual work can be started based on the result obtained by the above simulation.

➤ Optimization of lip angel can be done for better results.

➤ Analysis should be carried out at different velocities.

VI. ACKNOWLEDGEMENT

REFERENCES

[1]. "CAE analysis results" used in ULSAB-AVC concept design program toevaluate Structural concepts and to optimize structure. PES Engineering report in Oct2001.

[2]. T. Coppola, P. Picella, S. Segala, Centro Sviluppo Materiali R. Migliorin Acciai Speciali TerniF. Capelli, and Centro Inox "Numerical benchmark on materìal performance in anti-intrusion beams".explicit Finite element software for composite impact analysis".SAGE Publication,Australia in 2011.

[3]. Ron Brucker "Deep-drawing stainless steel mind the material" for Ulbric stainless steels and special metal in Oct 2001 .

[4]. H.Takuda,K.Mori,Masachika,E.Yamazaki and Y.Waranabe "Finite element analysis of the formability of an austenitic stainless steel sheet in warm deep drawing", Department of Energy Science Technology, Kyoto University, Japan in 2003.

[5]. Guancheng LI and Yonglin Kang "FEM Simulation of bending Formability for stainless steel" Dept. of basic science subjects, Huaihai Institute, Lianyungang,China in 2003.

[6]. Erik *Schedin* "Forming stainless steel for cost reductions and product consistency improvement". Atlas steel product company, Twinsburg in 2006.

[7]. V.Talyan, R.H. Wagoner, and J.K.Lee "Formability of stainless steel", the manuscript submitted to the Ohio state university, Columbus. In Nov 2007.

[8]. Mir Safiulla, Mohammed Naveed, Hemalatha, Sindushree and Vinutha "Optimization of the geometry of canister-Arrestor and heat treatment of 202 stainless steel canister" A Report submitted to VTU,Belagaum in 2011.

[9]. Mir Safiulla, Mohammed Naveed, Deepika A C and Divya, "Optimization of The geometry, material and heat treatment of stainless steel canister for compressed air bird-specimen and ice-pellet launcher" Proc. of International conference on Advanced Materials, Manufacturing, Management and Thermal Sciences, AMMMT-2010, 18-19 Nov 2010, SIT, Tumkur.

[10]. Clough.R.W "The finite element method in plane stress analysis." Proceeding
American Society of Civil Engineering 23: 345-378, 1960.