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Design Optimization of Foldable Hangar Door for Naval Ships

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Abstract - **After landing of helicopter on the deck of naval ship, it is to be protected from the sea atmospheric condition. For this purpose, a parking area is available on the deck of ship. The aft end of helicopter is enclosed in the hangar on deck of ship with the help of Foldable Hangar Door system. It is two door panel system which are foldable hanging type at the hinges at the top of hangar. The purpose of this system is only for proper movement of helicopter and its protection from different sea states conditions. In this project, after studying the available Foldable Hangar Door, different site issues related to the reliability of system are observed and that are tried to overcome by providing alternate possibilities as well as design optimization of system is done for the improvement of performance of system. In this project the issues which were causing difficulties are modified with new design and with some alternate solutions. The new system of Foldable Hangar Door is modeled and designed with performing the analysis of the new alternate possible solutions and are compared with the old design system in each aspect including weight of system, the performance of system etc. The system is also analyzed for different loading condition including sea atmospheric conditions are compared with the old design and found to be performing well. Hence new design approach of the system is further proceeded for the approval of customer where it will be validated for the specified system operating condition which are already specified by them while doing the designing.**

Index terms - Foldable Hangar Door (FHD), Top Lock Pin, Top Lock Assembly, ALJO Door, MAFO Door, Primary Assembly, Secondary Assembly.

I. Introduction

In Naval ships when helicopter is landed over deck, it needs to be carried to the parking area. This parking area is closed with the help of some door system so as to ensure the proper parking or enclosing of helicopter from sea atmospheric conditions. The foldable hangar door is used to enclose aft end of the helicopter structure. With the help of this door system the helicopter is safely parked into the area and its movement is not constrained by any part of system [1]. The detailed description of foldable hangar door is given below.

The overhead door is a foldable panel type designed to be mounted on to a fixed structure at a slope of 7 degrees to reduce the Radar Cross Section. The door consists of two foldable fabricated suitable marine grade material panels, which are interlocked to form a door. The panels rotate about its hinges with some suitable material, in up and down with the help of hydraulic cylinders, which are attached to the top of the hangar. The panels rest on the front walls of the hangar, so that it seals and provides support against wind pressure. The top and bottom door panel has separate cylinders for actuation. Function of Foldable hangar door is to opening & closing for

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movement of helicopter. The door can be operated remotely, electrically, manually or hydraulically (in case of emergency). The door is operated by a power pack along with cylinders and push buttons. The power pack is located inside the hangar [1].

One pair of hydraulically operated plunger cylinder is provided for each door panel for additional mechanical locking.

Figure 1 – Foldable Hangar Door [2]

Detailed description of foldable hangar door is shown in the figure 2. The Helicopter Hangar Door is used to enclose the aft end of the hangar structure. The door is a foldable type designed to be mounted on to a fixed, hangar structure supported at the top of the naval ships or Marine ships [2]. It consists of following major sub-assemblies are described as follows -

- Primary Door Panel Assembly
- Secondary Door Panel Assembly
- Primary Cylinders
- Secondary Cylinders
- Hinge Assembly
- Hydraulic Power Pack (with Pipes and Fittings for the Door)
- Emergency Power Unit (Electric Motor)
- Different Locking System

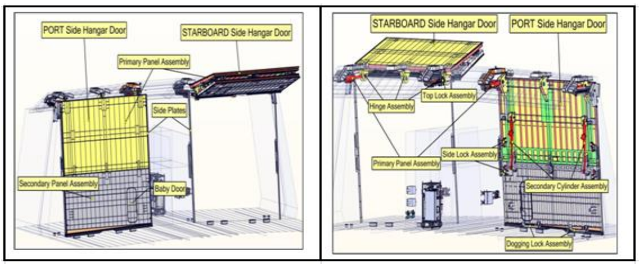

Figure 2– Foldable Hangar Door System (3D model) – Front view & Back View

A. System Specifications

The detail description of the customer requirement called Statement of Technical Report is provided to the Larsen & Toubro in which various specifications are described [3]. The system specifications are as follows: -

i) General Specifications

- Method of operation - Remote/ auto/ manual/ pneumatic
- Quantity of doors - 2 per ship
- Min. clear opening(mm) – 6000 x 6196 mm
- Approximate weight of system – 12.3 tons (5.48 tons of port side door & 5.48 tons of starboard door)
- Operating time in electrical mode of operation - 2 minutes approx. (open/close)

ii) Service Conditions

- 1 Blast Load - Sustain 0.5 bar without distortion (neglect)
- Wind Speed - Sustain115 Knots
- Rolling - Up to ± 45°
- Pitching - Up to ± 15°
- Shock - IN Shock Grade “A” for Destroyers, Frigates, Corvettes & NSS Grade II for others
- Rolling Period - 10 seconds (Unless otherwise stated)
- Pitching Period - 10 seconds (Unless otherwise stated)

iii) Atmospheric Conditions (Extreme)

- Ambient air temperature - 45°C
- Compartment air temperature - 55°C
- Sea water temperature - 35°C
- Relative Humidity - 100 % at 35°C

iv) Electrical Specification

- Electrical power requirement - AC 380V, 50Hz, 3ph

B. Working of Foldable Hangar Door

i) Door Opening

- Supply to MCP
- Selection of electrical motor (Main or stand by)

- Opening of locks - Dogging Locks & Side Locks
- Opening of Door from 7° to 60°
- Folding of Secondary Panel from 0° to 165°
- Opening of Door from 60° to 105°
- Engage Inter Panel Lock and Primary Lock

ii) Door Closing

- Open Inter Panel Lock and Primary Lock
- Closing of Door from 105° to 60°
- Un-folding of Secondary Panel from 165° to 0°
- Closing of Door from 60° to 7°
- Engage Dogging Locks & Side Locks
- Power off to MCP

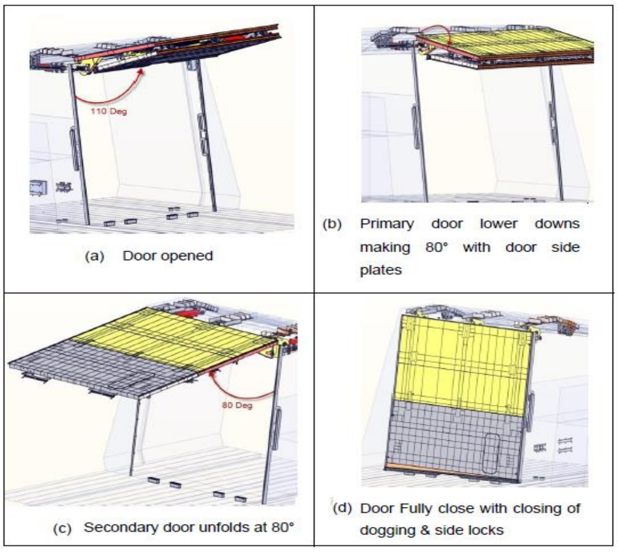

Figure 3– Working of Foldable Hangar Door System

C. Objectives of Project

i. Door frame requirement - Designing of door frame would help in reducing time and resources for installation at site. With the help of door frame major site work like welding and other machining processes for installation could be reducible so saving of site work time as well resources is possible.

ii. Use of light weight structure – As per the customer requirement it is suggested that Blast Load of 0.5 Bar should be ignored for new FHD model. So it would be possible to reduce the weight of system by reducing stiffeners as well as their height from 170 mm to 50 mm. We could also do the designing by using composites materials or aluminum alloys to reduce weight as well required forces for operation.

iii. The top lock assembly needs to be modified - It consists of complicated assembly of male lead screw rod, female lead screw part and other parts such as main frame, pipes, guide rods, jaw coupling etc. having complicated working and takes much time near about 2.30 minute for operation. So, some new top lock design with simple working could be possible for design for reliability of top lock.

iv. Finding out the system power requirement for operation.

v. Also, to find out time required for opening and closing of door system.

Some other standard foldable hangar door has been studied and compared with L&T doors.

ALJO-foldable hangar door is having the same design as that of Foldable Hangar Door of L&T but only the difference is that it consists of door frame in between the hangar structure and door panels. Total weight of system is near about 4500 Kg which consist of primary panel, secondary panel, door frame, primary cylinder, secondary cylinder and other hydraulic structure etc. In this type of FHD the sealing in between the door frame & door panels and in between the door panels is independent of Hangar fabrication. Because of this type of FHD no major work on Site like welding for the installation of it. Also, it saves more time during the installation at site because of easy installation process. As the door frame is in the consideration it achieves very effective sealing with the help of pneumatic system and also the mounting of sealing is achieved very easily [4].

Schweiss Hydraulic Bi-Fold Hangar Door is single panel; single cylinder hangar door consists of following parts [5].

- Door frame Header tube – it acts as the storage
- Cylinder support leg – it is used to support the cylinder one end with the help of pin support and with some specific distance.

- Lift cylinder – this cylinder acts as working body for the operation of panel for its closing and opening movement.
- Door frame Header leg – it acts as support for the panel of hangar door and the door panel
- Door seal – sealing is done for avoiding the external particles to enter in to the system
- Door frame – it is panel like structure which acts to closing and opening of system.
- Door Hinge – it is used to support the panel of door on to the door frame.

MAFO Foldable Door is made up of various layers called as stacks which are attached to each other and to the door frame. The opening & closing of Foldable Door is done by operating stacks with the help of chain drives. It is light weight in design as the stacks are made up of aluminum alloys. The Foldable door requires small space for enveloping it. The system is custom built which is based on MAFO design. It is having weather tight as well light tight arrangement as like sealing. The system is shock qualified. The durability is enough to withstand the load. The system is easy to install and also ease to repair possible on board with simple tools [6].

Navalimpianti Hangar Door is consisting of multiple panels, vertically sliding or folding type and suitable top frame. When Door opens with the help of hydraulic cylinder it rests on the top frame. Side door structures of the hangar door are integrated into ship structure. The tightness between the openings is achieved with the help of rubber gasket. The door panel operation may be realized by side chains operated by a reduction gear [7].

Operation of Ro-Ro external / internal top-hinged door is through the use of two direct-acting hydraulic cylinders located one on each side. Only one cylinder located at the center is sufficient to raise the door to its open position. When fully open ensures full free height is always available under the door. The door is locked shut by hydraulically operated wedges incorporated in the ship’s structure [8].

Well-bilt Bi-Foldable Hangar Door is consisting of the panels made up of composites materials with some suitable metal frame to support it. The guide rollers are installed on bottom corners for the movement of the panel for folding and hanging it. The operation is done with the help of cables w-which are attached to both primary panels as well secondary panel for folding and hanging purpose and are operated by counter weight-balancing mechanism or with the help of vertical cylinders on side frame to ensure sliding of panels for folding and hanging purpose of door. All exterior corners are mitered & welded on four sides for strength and to prevent water or moisture from entering the frame insures the tight design. There is no weight on building indicates light weight design. Manual operation is possible up to the height of 3 m [9].

III. Methodology

A. *Material Selection*

Most of material which is going to use in this project is NVF 690 referred with the standard ASTM A514 which is readily available ultra high strength ship plate used for fixed offshore structure. NVF 690 ship steel is accordance with DNV specification. The standard specifies requirements for weldable steels to be used in fabrication of fixed offshore structures [10].

This material has been specially designed for offshore applications requiring the use of heavy thick plates (up to 250mm/10”) with demanding mechanical properties requirements. The chemical composition of NVF 690 has been carefully adapted and allows the achievement of high impact values across the thickness while respecting the tensile properties required and having yield strength of 690 MPa. The main application of NVF 690 is for forming, oxycutting and welding properties. The very low carbon content of this material allows cutting and welding under classical conditions, increasing in this way the cost efficiency of manufacturing [10].

B. *New Top Lock Design*

So, to overcome the reliability issues of old top lock assembly, new Top lock is modeled according to the space availability and ease of working. New top lock assembly is designed according to overcome the reliability issues of top lock design and described as follow [11].

i. It consists of cylinder-piston arrangement, locking pins, mounting plates having holes attached to the hinge assembly also the limit switches.
ii. Hinges having locking pin shaped curved shape design.
iii. Working of new top lock assembly - When the door is opened the limit switch at top lock arrangement will give signal to MCP and then expansion of top lock cylinder piston with attached pin will go through the hole based plates and will pass through the hinge having pin shaped mounting and will restrict the movement of door assembly.
iv. With the help of new design, assembly is having very less parts so takes less time for working of it.
v. Also, there are no issues of assembly parts falling down as well stucking of parts due uncomplicated assembly.
vi. In case of emergency (electrical supply fails) with the help of hand pump it is possible to close the door by pumping it.

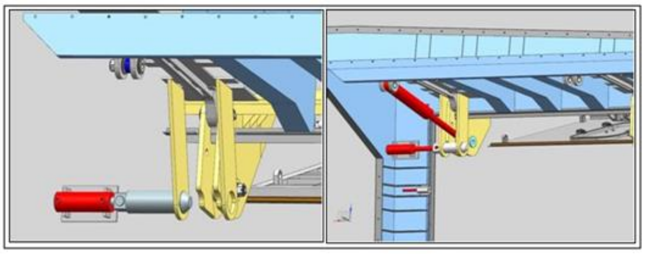

Figure 4: New Top Lock Model (Open and Closed condition)

C. New Top Lock Pin diameter design calculation

The locking pin diameter and cylinder force requirement for the working of top lock are found out by doing some design calculation [11]. For finding the locking pin diameter and cylinder pressure for working of top lock, some factors are considered [12] and are given as follows –

a. Door weight of both panels should be considered.
b. Door should be considered in its opened condition at that time only top lock will be opened condition.
c. No wind force is considered since door will be in opened condition at 110 degree.
d. Shear force and bending moment are considered while calculating the locking pin diameter.

Weight of door panel = 4480 Kg = 43948.8N

Distance of CG of door panel with respect to hinge centre = 1558 mm

Moment due to panel weight at hinge centre= 43948.8 × 1558= 68472230.4 N-mm

Distance of hinge centre from lock pin centre = 278.06 mm

Hence force acting on the lock pin = 68472230.4 / 278.04 = 246249.84 N

Number of lock pins considered as = 2

Hence force per lock pin = 246249.84 / 2= 123124.91 N

Length of lock pin is taken as = 250 mm

Moment due to force on lock pin = 123124.91 × 150 = 18468737.97 N-mm

We know that due to this moment on locking pin shear will occur in locking pin.

Hence Shear Stress = M × 32 / (3.14 × d^3)

We have considered the material NVF 690

Having Yield Tensile Strength = 700 MPa

Hence Shear Strength = 700 / 2 = 350 MPa

We considered, Factor of Safety = 2.5

Hence Design Shear strength = 350 / 2.5 = 140 MPa

Diameter of lock pin = 110 mm

D. Opening Time requirement calculation for Opening and Closing of Door System

The time required for opening and closing of Door system is calculated by using Displacement calculation of Primary and Secondary Cylinder and is given as follows –

We know that,

For Primary Cylinder

- Cylinder Bore = 150mm
- Piston Stroke = 750 mm
- Cylinder Piston Diameter = 70 mm

Hence Displacement at

At Cap End of Cylinder = (Piston Stroke × 3.14 × 0.15^2) / 4 = (0.75 × 3.14 × 0.15^2) / 4 = 13.2 Liter

At Rod End of Cylinder = (Piston Stroke × 3.14 × (0.15^2 - 0.07^2)) / 4 = (0.75 × 3.14 × (0.15^2 - 0.07^2)) / 4 = 10 Liter

Now for Secondary Cylinder

- Cylinder Bore = 150 mm
- Piston Stroke = 850 mm
- Cylinder Piston Diameter = 60 mm

Hence Displacement at

At Cap End of Cylinder = (Piston Stroke × 3.14 × 0.15^2) / 4 = (0.85 × 3.14 × 0.15^2) / 4 = 15 Litre

At Rod End of Cylinder = (Piston Stroke × 3.14 × (0.15^2 - 0.06^2)) / 4 = (0.85 × 3.14 × (0.15^2 - 0.06^2)) / 4 = 12 Liter

Assuming,

- Pump Discharge = 19 cc
- Volumetric Efficiency = 90%
- Motor Speed = 1450 rpm

Hence calculating Pump Delivery = (Volumetric Efficiency × Pump Discharge × Motor Speed) / 1000 = (0.9 × 19 × 1450) / 1000 = 25 LPM

Time for Opening the Door System = (No. of Cylinders × (Disp. of Primary Cylinder from Cap End + Disp. of Secondary Cylinder from Rod End)) / Pump Delivery = (2 × (13.2 + 12)) / 25 = 121 seconds

Time for Closing the Door System = (No. of Cylinders × (Disp. of Primary Cylinder from Rod End + Disp. of Secondary Cylinder from Cap End)) / Pump Delivery= (2 × (10 + 15)) / 25 = 120 second

IV. Result And Discussion

A. Static analysis of Foldable Hangar Door

i. Static analysis of Foldable Hangar Door is done to verify its sustainability for given operating condition. In this static analysis, the effect of wind load and body panel weight is observed by constraining the door system properly as discuss below. The Foldable Hangar Door modeling is done with the help of Solidworks R12.0. The analysis is done with the help of Ansys R15.0 APDL and results are calculated.

ii. For this static analysis boundary conditions considered are as follows -

   a. Top faces nodes of main hinge are arrested in all DOF.
   b. Cylinder mounting hinges are arrested in all directions.
   c. Side faces of door are arrested in x-direction
   d. Bottom face of secondary panel is arrested in x and y directions
   e. Nodes at the coupling between primary and secondary panel are arrested in all DOF
   f. Nodes at the coupling between main hinge and Primary panel are arrested in all DOF

iii. Loading Conditions for given static analysis are given as follows

   - As per customer requirement blast load is not to be considered.
   - Wind load of 60 Knot is considered on both Primary and Secondary Panel
   - Body weight i.e. weight of Primary and Secondary panel is applied.

iv. . The results of the static analysis are calculated and are studied as follows.

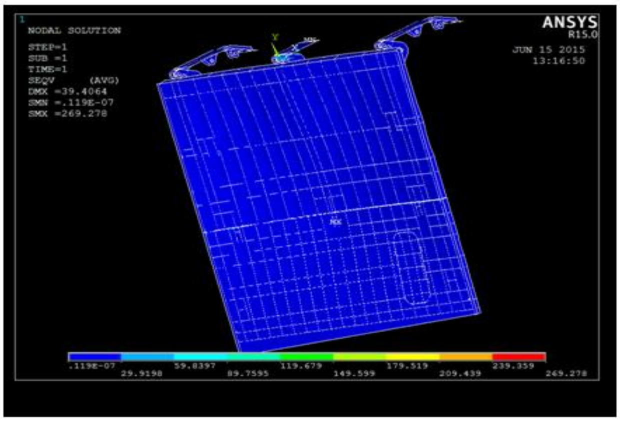

Figure 5 – Von Mises Stresses Plot for FHD

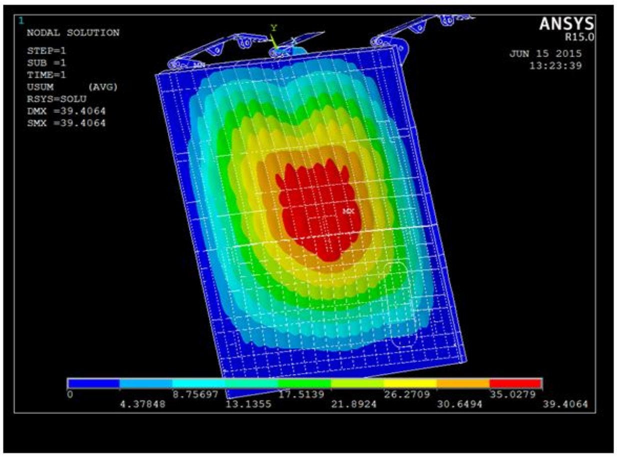

Figure 6 – Total Displacement Plot for FHD System

From the Von mises Stress plot shown in figure 5, it is observed that the stress value comes out to be 269 MPa which is then compared with the material strength of NVF 690 having yield value of 690 MPa. Stresses obtained are within limit and the design of Foldable Hangar Door is safe.

From the displacement plot shown in figure 6, it is observed that the total deflection of the Foldable Hangar Door comes out to be 39 mm but it is observed to be within limit as per the given customer requirement. The maximum deflection is obtained at center of system so that part is made more strengthful by providing stiffeners.

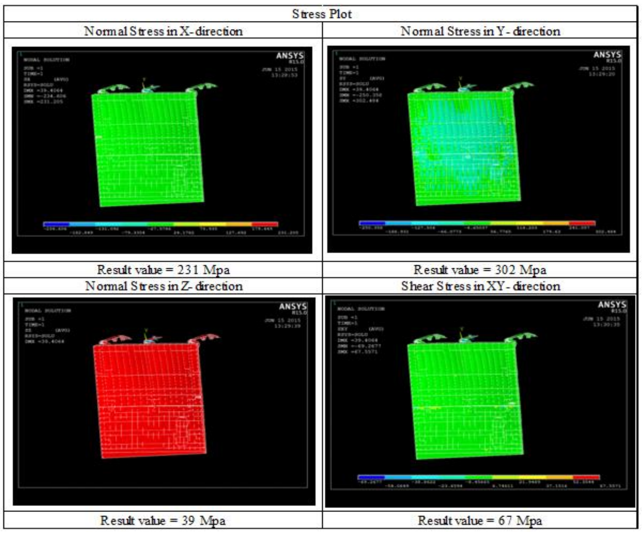

Figure 7 – Normal Stress and Shear Stress Plot for FHD System

From figure 7, it is observed that the normal stresses in X and Z direction are less that the Von mises Stresses i.e. 269 Mpa and Stress in Y direction is more than Von mises but as it is directional stress so it is ignored and main focus will be on Von mises stress.

B. Static analysis of Top Lock Pin

Analysis of Top lock pin for the moment generated due to body panel weight of the door system is done by using Ansys R15.0 and for the purpose of this model is prepared by using Solidworks R12.0. Steps followed during analysis are as follows –

- Only body panel weight is considered as worst case
- We already have diameter of locking pin 120 mm and length of locking pin = 250 mm
- Meshing is done by using Hex Dominant Method with size of 10 mm and also used fine meshing.
- Boundary condition – we have fixed the one side of locking pin as fixed support
- Loading condition – we have applied the moment of 18468737.97 Nmm generated due to self weight of door panels.
- The Von mises plot of locking pin is observed as follows - The von mises stress value = 68 MPa

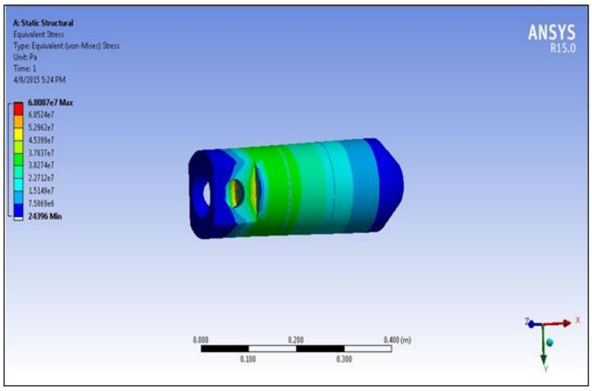

Figure 8– Von mises plot for Locking Pin

- The deformation of locking pin is observed as follows – The displacement value = 0.06 mm

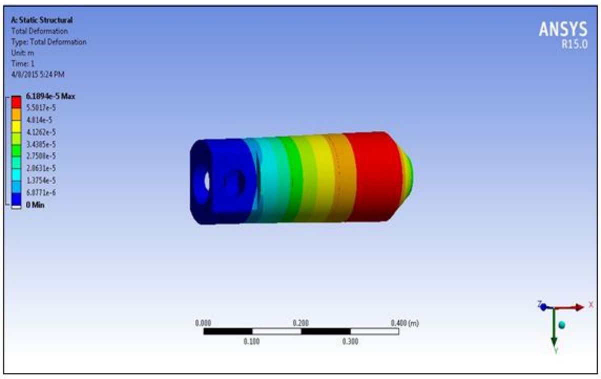

Figure 9– Displacement plot for locking pin

From figure 8, the Von mises stress calculated from the analysis of locking pin are observed to be less than the material design strength. Hence the locking pin modeled and designed is safe for operation of top lock to hang the door when it is in opened condition.

IV. Conclusion

- With the help of new modular approach of using door frame, resources used at site work are effectively reduced.

- Effective weight reduction in new FHD model is achieved.
- With the help of light weight designing, system power requirement is minimized.
- Major issues of FHD are regarding top lock reliabilities. Hence are minimized with the help of new design.
- Also, time required for the opening and closing of door is calculated so it will help in comparison with actual one.
- New Side lock design will help in getting proper fitting of door panel in hangar as well effective sealing is achieved
- Because of reduction in weight of system, the shock loading can also be minimized.

V. Acknowledgement

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