



KINEMATIC AND DYNAMIC ANALYSIS OF HATCH QUICK OPENING/CLOSING MECHANISM FOR CANISTER

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Abstract: The efforts required in achieving the desired output can be effectively and economically be decreased by the implementation of better designs. A system and method for actuating a hatch door. Ammunitions are commonly transported to battlefields within canisters to avoid environmental exposure and cushion against vibrational damage.

A vertical launcher system (Canister) that consists of a hatch door at the top of the hold of the vertical launcher system. This door mechanism enables both opening and closing of the door. For quick opening and closing of hatch door a four-bar mechanism has been designed. A crank-rocker inversion of four-bar mechanism is designed for opening and closing of hatch door of canister.

The hatch door opening closing mechanism is simple and easy in operation. The significance and purpose of this work is to provide smooth and quick opening and closing of hatch door during a launch system and also ensure to safeguard the article stored inside the canister launching system.

I.INTRODUCTION

1.1 Field of project:

This invention relates to opening and closing mechanism particularly. Particularly, this invention relates to vertical ship launchers. Still particularly, this invention relates to launching systems dominantly used in artillery.

1.2 Background of project:

A fuel propelled projectile, propulsion being engineered by the reaction of rearward discharged gases, liberated with great force when the fuel is combusted.

In many military applications, projectiles ready for launching are stored in canisters. The projectiles contained in a canister are mounted in its launcher. These launchers are capable of locating, holding and launching a plurality of an object which is forcibly propelled at a target. The type of launcher is chosen depending upon desired capability.

The hatch door provides a protective cover and acts as a seal for the projectiles in the cells from the environment during storage, transportation and exploitation. The hatch cover is locked in closed position with the help of a locking mechanism. During launching of a projectile, the respective hatch of the cell containing the fired weapon is opened by the operation of the locking mechanism.

1.3 About the Canister:

CANISTER is a cylindrical container for holding, carrying, storing and launching of an article. Usually specified object or substance. In launch system, the launch canister technology has been widely used in many kinds of rockets launch system because of the advantages of convenient maintenance, fast reloading of ammunition, and universality for launching various kinds of rockets with different calibers.

Function of Canister:

The launch canister has two functions: Canister is a pressurized canister, which will enable environment protection of article during storage transportation.

1.4 About the hatch door mechanism

Hatch Door Mechanism:

The hatch door should ensure pressurized storage of article and it should be quick open prior to launch of article. The hatch should be opened from a single command from Canister Mechanism Relay Unit (CMRU) During storage and transportation of article canister will be pressurized with 1.15 bar absolute pressure. Hatch should have leakage proof locking for this purpose. Also, quick opening prior to launch and near close position post launch is required. So it's a front door mechanism use in projectile. It is a 4 bar Linkage mechanism. It's a one mechanism for door opening and closing as well. Where that door will open at time of 0.5 sec. This is compact door opening as well as closing mechanism.

II. LITERATURE REVIEW

ROTATING AND SLIDING HATCH DOOR MECHANISM FOR A LAUNCHER SYSTEM

Inventors: Corey A Fleische, Bruce S Chiu, Kristopher Heick

A system and method for actuating a hatch door. One embodiment includes a vertical launcher system that consists of a hatch door at the top of the hold of the vertical launcher system. The hatch door has a leading edge and a trailing edge at opposite ends of the hatch door. When an actuator arm for maneuvering the hatch door is extended, the leading edge is lifted away from the plane by the actuator arm while the trailing edge remains in the plane and slides across the top of the plane toward the point where the leading edge was first lifted away.

Aircraft, ships, special-use vehicles, and other vessels may have hatches with hatch doors that may be opened and closed for various uses. For example, a land-based vehicle with a canister may have an external hatch with a movable door that may be opened and closed. As another example, a water vessel may have a hatch with a movable hatch door that may open when the article is to be launched and closed when the article is to remain in the hatch.

By applying the actuation force directly to the leading edge 211, the full force of the actuator may be applied to breaking ice build-up or rust. This is an advantage over conventional system that would not apply the full force of the actuator as the conventional linkage system introduces a significant mechanical disadvantage. If the system is deployed in harsh environments with cold temperatures, this may result in ice build-up on and around the hatch door. If the ice build-up is great enough, the actuation of the hatch door may be compromised. Other environments may cause a build-up of rust that also may prevent the hatch door from actuating properly.

LAUNCHER TUBE ACCESS DOOR

Inventor: John F Witherspoon Earnest R Foreman

In the past, access doors for launching tubes have been operated mechanically, hydraulically or electrically, and which mechanism was combined with an emergency manually operated system which was often inadequate. The manual system was designed to be used only when the other system failed. To manufacture a door having the two systems was costly and time consuming. The access door is used, generally for maintenance and inspection, and at times when there is no hurry. It is not a cog in the sequence and has no function to perform which makes it necessary to operate in synchronism with other pieces of mechanism. The door could be made much less expensive and serve the same function if the only mechanism for operating it was manually operated.

Three manually operated access door mechanisms on the launcher tube, in line with access doors on the outer tube. The two lower door mechanisms provide access to the missile second stage jetevators and interstage equipment. A switch on each door mechanism indicates to the launcher control panel, whether or not the door is locked. The switch also interlocks control circuits to prevent hatch opening or pressurization if a door is unlocked.

2.1 Problem statement:

Design and development of kinematic and dynamic analysis of hatch quick opening/closing mechanism for canister in order to ensure quick opening and closing of hatch door at 90 degree crank angle

2.2 Objectives:

- 1) To provide a mechanism which allows quick opening and closing of hatch door.
- 2) The hatch should be opened from a single command from Canister Mechanism Relay Unit (CMRU).
- 3) Hatch door should open from 0 degree to 93 degree prior to launch and should come back to initial 0 degree position post launch.

2.3 Scope of project:

The mechanism as described herein above offers several advancements. The operation of the hatch door mechanism is simple and reliable. The mechanism provides desired functionality required for opening and closing of hatch door.

2.4 Methodology:

The following are the aspects to be taken into consideration for accomplishing our project:

Design calculations of hatch mechanism are decided based up on canister dimensions and loads. From the calculations, a 3-D model of hatch is developed using SOLID WORKS.

III. CONFIGURATION AND DESIGN

The hatch should be opened from a single command from Canister Mechanism Relay Unit (CMRU) prior to launch of article. During storage and transportation of article canister will be pressurized with 1.15 bar absolute pressure. Hatch should have leakage proof locking for this purpose. Also, quick opening prior to launch and near close position post launch is required. The configuration and concept of operation of the front door opening mechanism is explained below paragraphs.

The gap of 16.91 mm is sufficient as per the tip off analysis being carried out as explained. This door mechanism enables both opening and closing of the door. The configuration of door mechanism is shown in the figure below.

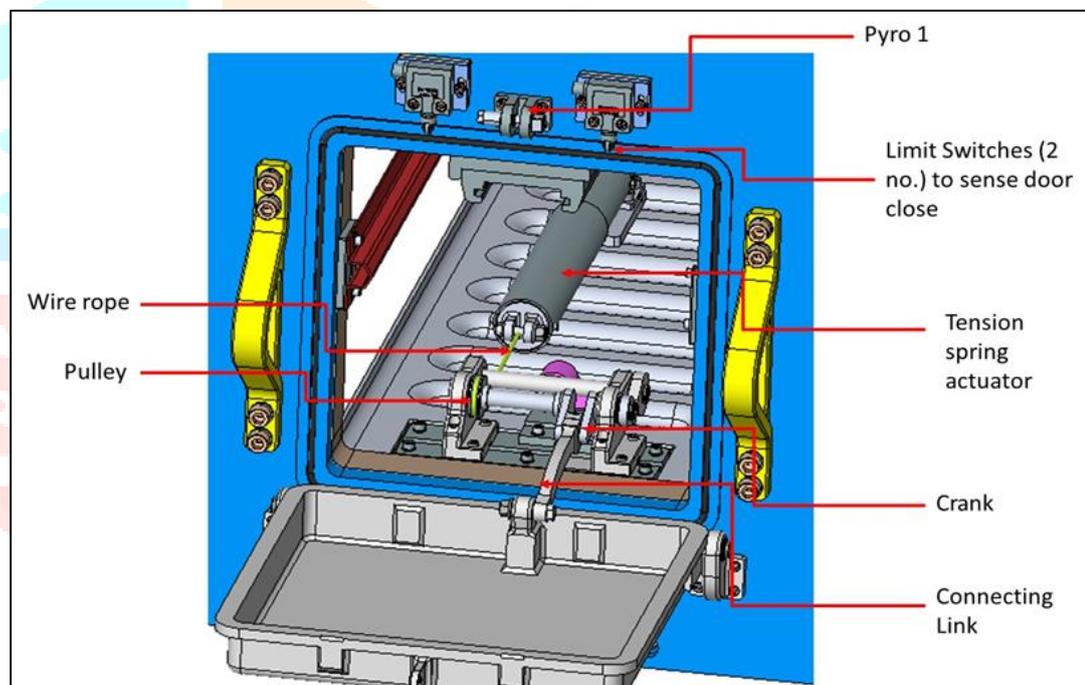


Fig 1 Hatch mechanism view 1.

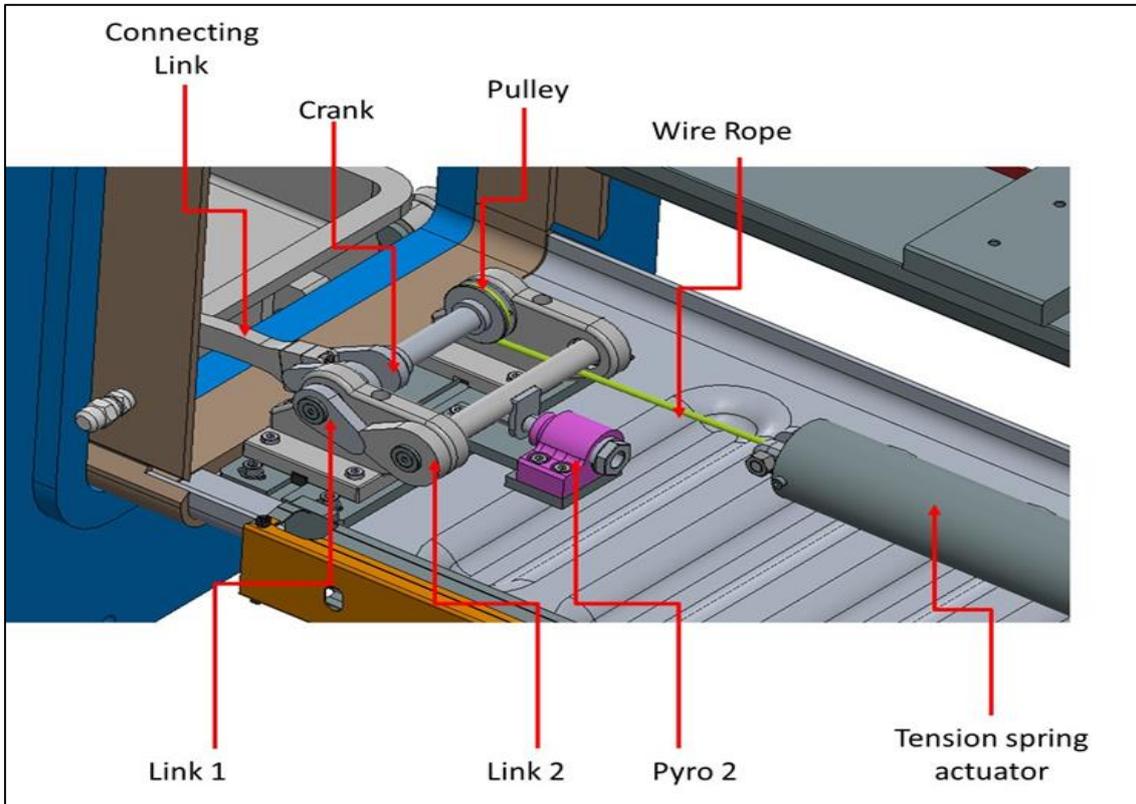


Fig 2 Hatch mechanism view

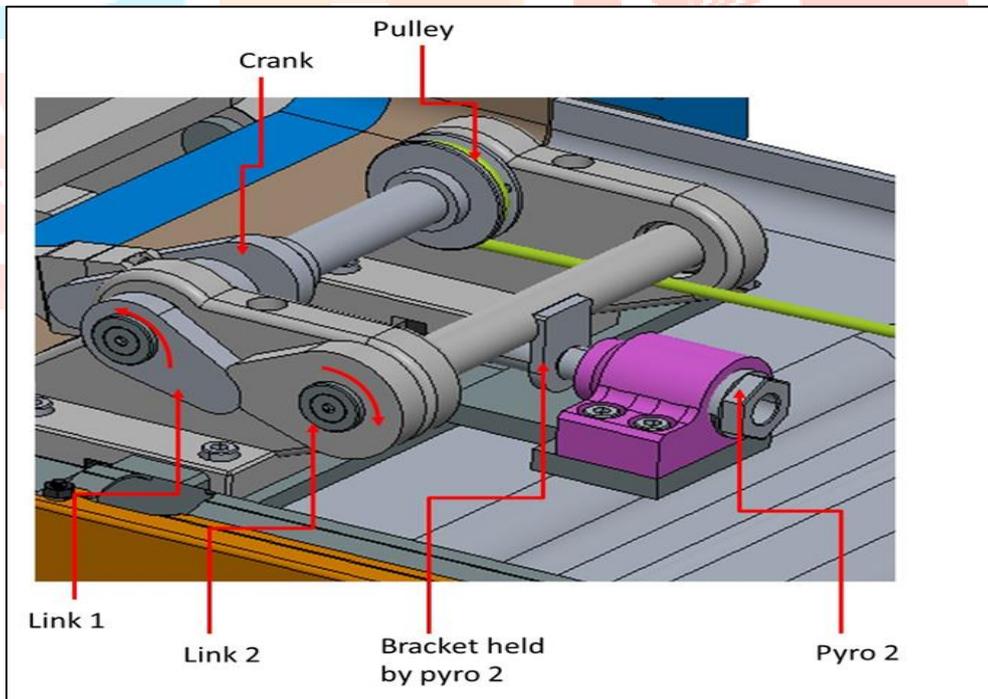


Fig 3 Hatch mechanism view

For its intended purpose, hatch door will be locked by a pyro bolt arrangement.

In this mechanism, the crank makes full 360 deg rotation, the connecting link acts as a coupler between the crank and the door. The door is the rocker of the mechanism which oscillates 0 to 92 deg in 0 to 180 deg rotation of crank. The door further oscillates back from 92 to 0 deg, as the crank further rotates from 180 deg to 360 deg.

There is a pulley provided coaxially on the shaft of the crank. The wire rope is wound on the pulley. One end of the wire rope is fixed to the pulley. The wire rope is wound more than 360 deg over the pulley. The other end of wire rope coming out from pulley is attached to the tension spring actuator. The spring inside the actuator is pulled towards the door to attach with the wire rope. The hatch door, in close position is locked by the pyro 1 bolt. As the pyro bolt 1 bursts, the tension spring moves away from the door pulling the wire rope. As the wire rope is wound over the pulley, the pulley rotates in CCW direction. As pulley is mounted coaxially on the same shaft of crank, the crank also rotates in CCW direction. Due to the rotation of the crank, the connecting link pushes the door to open position at 92 deg. There is a link 1 mounted coaxially on the same shaft of the crank. The link 1 also rotates CCW along with the crank. As the door opens the link 1 rotates and stops over the link 2. The shaft of the link2 is held static by the pyro 2 bolt. There is some more tension available in the tension spring actuator. Now to close the door, the pyro 2 bolt is bursted. The link 2 now becomes free to rotate in CW direction. As the pyro 2 bursts, the tension spring is further pulled away from the door, the pulley rotates further CCW, rotating the crank further CCW. As the crank further rotates, the connecting link pulls back the door to close position as shown in figure 6-29. The link 1 also rotates further CCW pushing the link 2 to rotate CW.

Material selection:

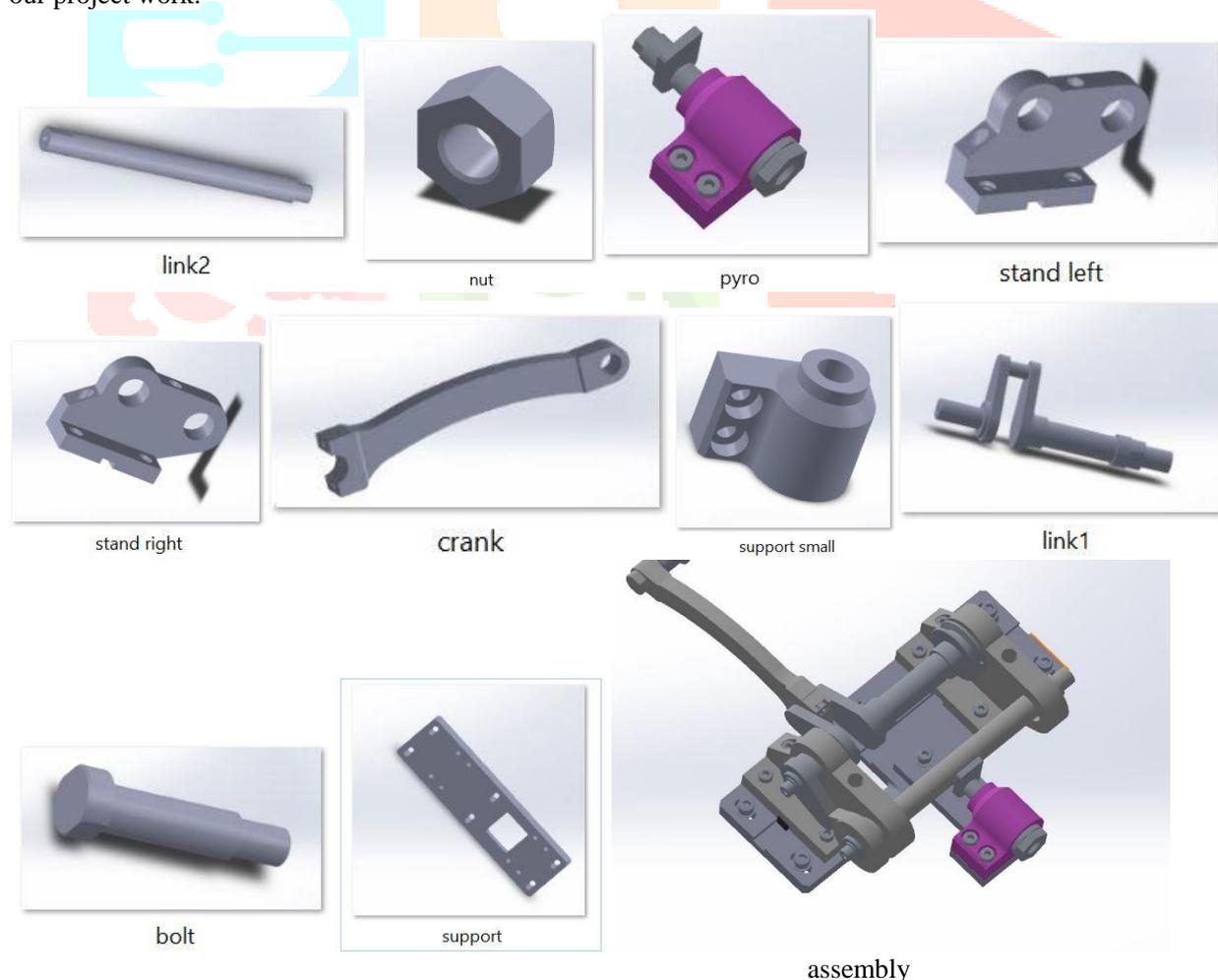
AA7075 Aluminium alloy has been used for all components.

IV. SOLIDWORKS MODELS

SOLIDWORKS INTRODUCTION

SolidWorks is a solid modeling computer-aided design (CAD) and computer-aided engineering (CAE) computer program published by Dassault Systems. SolidWorks is a solid modeler, and utilizes a parametric feature-based approach which was initially developed by PTC (Creo/Pro-Engineer) to create models and assemblies.

Some simple and basic parts, models and assembly are shown below for the better understanding of solidworks and its use in our project work.



V. DESIGN CONSIDERATION AND CALCULATIONS

Synthesis of Hatch Door Opening/Closing Mechanism

Dimensional synthesis of a linkage is the determination of the proportions (lengths) of the links necessary to accomplish the desired motions. The problem definition for linkage design of hatch can be stated as.

Hatch door should open from 0° to 93° prior to launch and should come back to initial 0° position post launch.

Dimensional Synthesis of mechanism has been carried out and the mechanism is optimized considering the following parameter

- Available space for accommodating the mechanism
- Overall length of the actuator considering stroke length required
- Axial Force on the Actuator and spring force
- Load Torque reflected at door pivot

For dimensional synthesis of mechanism, a number of iterations are made during kinematic analysis of mechanism to arrive at the final configuration of hatch door opening mechanism.

The Grashof condition is a very simple relationship that predicts the rotation behavior or rotatability of a fourbar linkage's inversions based only on the link lengths.

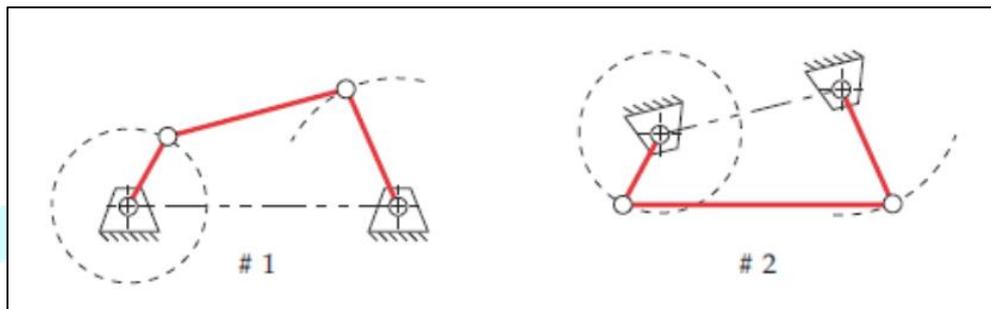


Fig 5 Two non-distinct crank-rocker inversions

Let:

- S : length of shortest link
- L : length of longest link
- P : length of one remaining link
- Q : length of other remaining link

Then if:

$$S + L \leq P + Q$$

The linkage is Grashof and at least one link will be capable of making a full revolution with respect to the ground plane. This is called a Class I kinematic chain. If the inequality is not true, then the linkage is non-Grashof and no link will be capable of a complete revolution relative to any other link. This is a Class II kinematic chain.

The motions possible from a four bar linkage will depend on both the Grashof condition and the inversion chosen. The inversions will be defined with respect to the shortest link. The motion chosen for hatch is:

Class I case, $S + L < P + Q$:

Ground either link adjacent to the shortest to get a crank-rocker, in which the shortest link will fully rotate and the other link pivoted to ground will oscillate.

A graphical approach for deciding of link length has been followed as shown in figure below, steps followed is shown below.

- Draw the output link O,V in both extreme positions, B1 and B2 in any convenient location, such that the desired angle of motion 93 is subtended.
- Draw the chord B1B2 and extend it in any convenient direction.
- Select a convenient point O2 on line B1B2 extended.
- Bisect line segment B1B2, and draw a circle of that radius about O2.
- Label the two intersections of the circle and B1B2 extended, A1 and A2.
- Measure the length of the coupler as A1 to B1 or A2 to B2.
- Measure ground length 1, crank length 2, and rocker length 4.
- Find the Grashof condition.

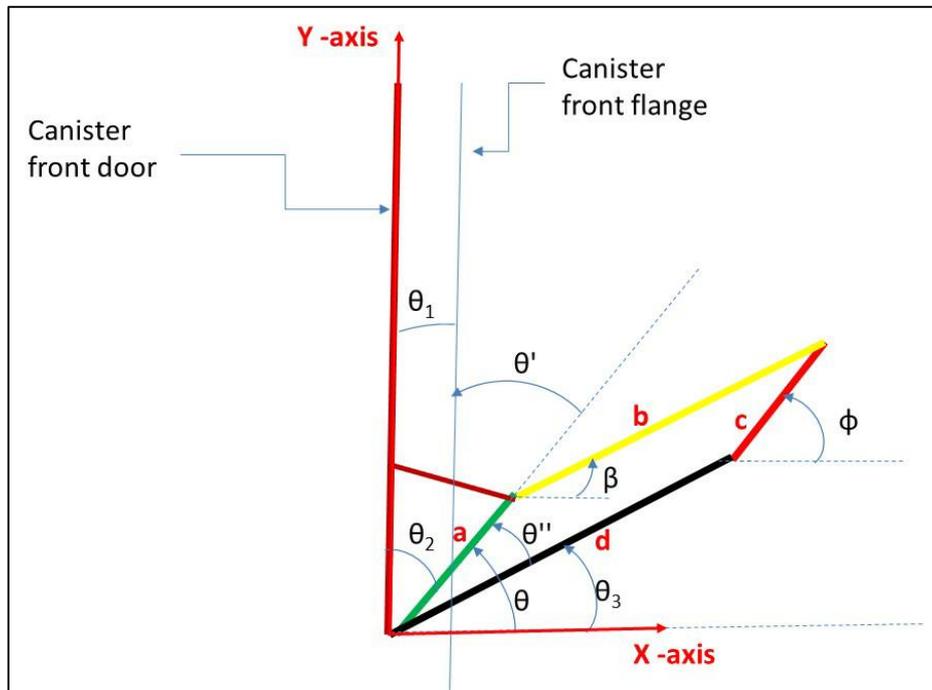


Fig 8 Kinematic Linkage through Dimensional Synthesis (Door at closed position)

In above figure , links ‘a’, ‘b’, ‘c’ and ‘d’ form the four bar linkage.

Rocker – link ‘a’

Connecting link – link ‘b’

Crank – link ‘c’

Fixed link – link ‘d’

θ – angle between link ‘a’ and x -axis

ϕ – angle between link ‘c’ and x-axis

β – angle between link ‘b’ and x-axis

θ_1 – angle between door and canister front flange

θ_2 – angle between link ‘a’ and door

θ_3 – angle between link ‘d’ and x-axis

θ' –angle between link ‘a’ and canister front flange

θ'' – angle between canister front flange and link ‘d’

Fixed Dimensional details:

θ_2	50.6	deg
θ_3	25.91	deg
θ''	64.09	deg
a	54.35	mm
b	141	mm
c	38	mm
d	155.64	mm
Initial angle ϕ	30.46	deg
Pulley radius, R	15	mm

Checking Grashof Condition of Class I case, $S + L < P + Q$:

$$c+d < a+b$$

$$38 + 155.64 < 54.35 + 141$$

$$193.64 < 195.35, \text{ hence satisfied.}$$

Design considerations and criteria:

- Position Analysis of Hatch Door Opening/Closing Mechanism
- Force Analysis and Estimation of Spring Force
- Estimation of hatch door opening/closing timing
- Design and Sizing of Spring
- Design of the Tension Spring Actuator Inner and Outer Cylinders
- Design of actuator bottom and top pivot pins
- Design of hatch door pivot pins
- Design of Linkages and pivot pins
- Design of wire rope
- Design of Pyro bolt housing

VI. SIGNIFICANCE AND CONCLUSION

The hydraulically operated hatch opening and closing mechanism help in reducing the operational and the maintenance cost of the canister mechanism. The hatch locking and unlocking mechanism for a canister of the present invention helps in reducing maintenance of the system. The hatch locking mechanism helps in facilitating the opening of hatch during emergency launching. The mechanism is lighter in weight and cost effective.

Therefore the mechanism as described herein above offers several advancements over other mechanism in the same domain.

REFERENCES

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