Separation Connector

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Project Update

Document

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1. Problem Statement

The goal of this project is to design and prototype a relatively easy to manufacture, inexpensive, and perfectly reliable separation connector.

1.1 Introduction

Orbital Sciences Corporation is an engineering design company that contracts in space vehicles and missile defense systems. Our sponsor from Orbital Sciences Corporation is Mary Rogers. She is the current electronics packaging and actuator manager. She has requested, on behalf of Orbital Sciences Corporation, that our capstone group aid in redesigning their current separation connector. The separation connector is the device that allows the launch vehicle to de-mate from to the device being deployed. It is a mechanical device that detaches the communication wires of the launch vehicle and the deployed device. Ideally, this new separation connector will be easy to manufacture, lightweight, and more effective than its predecessor.

Figure 1: Current separator connector

1.2 Needs Identification

Mary Rogers approached us with this project in hopes of improving the current separation connector. She had some specific requests on what her company was looking for. Some of her requests included:

- The device being able to withstand military specification testing
    - Including but not limited to thermal, shock, and vacuum tests
- The device should not de-mate prematurely
- The device should separate with a reasonable amount of force
    - For static separation, reasonable is defined as 10-30 lbf
- During dynamic de-mate, the device must be able to withstand a force of 200lbf
- The leash must be able to withstand a pulling force of 300lbf
- The device must be reliable enough to mate and de-mate a minimum of 50 times without failure or damage
- The male end of the connector is to remain unchanged
- Must be able to be easy to manufacture

From these needs, we concluded that the customer needs a separation connecter that is easy to manufacture, perfectly reliable, and can statically de-mate under smaller loads than are currently available.

1.3 Project Goal

It is essential that the new separation connector mates and de-mates at least 50 times with no signs of damage or failure. Thus, the goal of the project is to design an improved separation connector that will separate cleanly 100% of the time. Static de-mate, for this new separation connector, will be achieved when a force of 10-30 lbf is applied to it and it will be able to withstand a force of 200lbf during dynamic de-mate. Lastly, the entire design will be easy to manufacture so that it can be machined in-house by Orbital Sciences Corporation’s machine shop.

1.4 Constraints

This section includes the specifications to which our design must abide by. These constraints were given by our client to ensure the separation connector meets Orbital Sciences Corporation's rigorous standards. Below is a list of the required specifications:

- Bayonet grooves must match military specifications
- Must de-mate statically with a force ranging from 10-30 lbf
- Must be able to withstand a minimum pulling force of 200 lbf during dynamic de-mate
- Leash must be able to withstand a minimum pulling force of 300lbf
- Must be able to statically mate/de-mate a minimum of 50 times without failure
- Must withstand a temperature gradient of -34°C – 71°C with no damage to the material
- Must withstand a static acceleration of 15 G-Force
- Must not fail during a drop test
    - From a height of 3 feet dropped onto a concrete floor
- Must pass a "rattle test"
    - The object is shaken by hand, or in a vibration machine, and must not rattle or de-mate
- Must not exceed an increase in size of 25 % greater than the original (~1.43" inner diameter for male end)
- Must not exceed an increase in size of 25 % greater than the original (~1.42" outer diameter for female end)

2. Final Design – Ball Bearing Detent

The "Ball Bearing Detent" design is our final design that we will prototype. This design has undergone extensive modifications in order to meet the requirements and constraints given. The new design consists of six part major pieces: a male end, a female end, a coupling connector, a pressure plate, the ball bearing retention ring, and the leash ring. The minor pieces include: a wide spring for the pressure plate, six ball bearings, six smaller springs that rest behind the ball bearings, and a leash cord.

This design will statically de-mate when a force of approximately 30lbf is applied to both ends in opposite directions. This condition is also true for dynamic de-mating as the separation connector will be located inside of a rocket and will not experience too many external forces.

However, the device has potential to experience higher pull forces during flight as opposed to being on the ground. These higher forces are the forces experienced when, for example, a rocket has separating stages. When the stages separate, one end will continue its flight causing a high pull force on all of the internal components. To account for these high pull forces, we have designed our separation connector to be able to withstand forces of up to 200 lbf. This ensures the parts used in separation connector will not shear or catastrophically fail due to instant "shock" forces that may happen during flight.

2.1 Final Design Description

This design, shown in figure 1 below, utilizes the original male end and a modified female end. Both ends connect to each other by being inserted into a third piece, the coupling. There are two ways to insert the two ends of the separation connector. The first style is called a "twist-pull" style. The male end inserts into the coupling by twisting it clockwise one-third of a turn, which allows the bayonet pins to follow a track on the inside of the coupling. When it reaches the end of the track, the pressure plate inside of the coupling applies an opposing force that forces the bayonet pins into a groove and mates the male end to the coupling which will achieve a mate. The second style of mate is called a "push-pull" style mate. In this type of mating, the female end is forced into the back of the coupling. When the female end is pushed into the coupling, the ball bearings will retract allowing it to enter the coupling. When the ball bearings reach the inner groove cut into the coupling, the ball bearings will expand and mate the female end to the coupling.

In order to de-mate the device there must be a pulling force on both ends of the connecter. The ball bearings on the female end will retract when approximately 30lbf of force is applied to them. This allows the female end to detach both statically and dynamically. For static de-mate of the male end, the male end must be pushed down and twisted counter-clockwise one-third of a turn simultaneously. The male end will not de-mate during dynamic conditions. Instead, the female end will be removed and the coupling will stay with the male end.

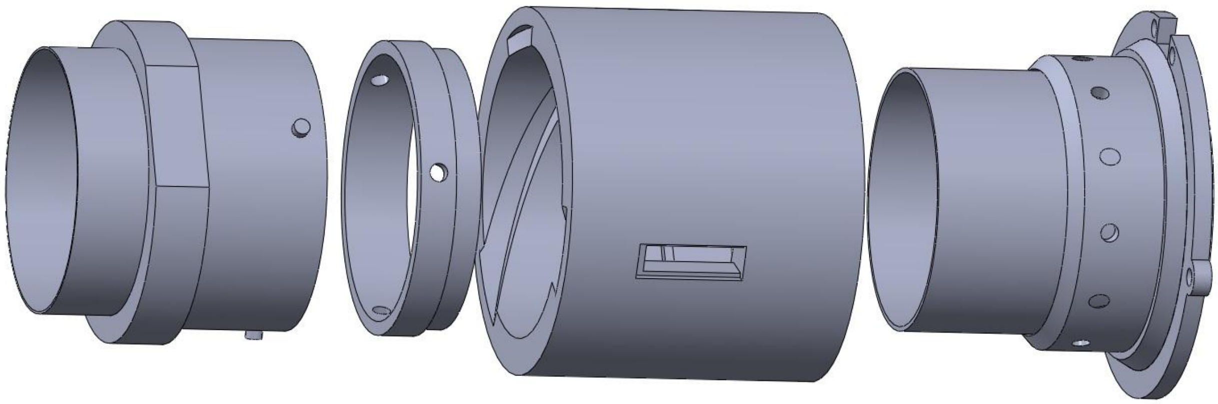

Figure 2: Exploded-View of Final Design

2.2 Major Pieces

- Male end
  - Due to the customer's constraint, we were unable to change this part. Therefore, this part remained the same as the original design.
- Female End
  - This piece is a simplistic shell that holds all of the communication wires. It has an extrusion on the bottom half with holes tapped in it to hold the springs that apply force to the ball bearings. It will contain the springs and ball bearings when the ball bearing retention ring is put on.
- Coupling
  - This piece is a coupling that has grooves cut into both ends to accept both the male and the female ends. The end that accepts the male end has a helical groove that allows the male end to rotate one-third of a turn (as per military specifications). The end that accepts the female end has a circular (180°) groove cut into it to accept the ball bearings. When the ball bearings are pushed into the coupling, they compress. The ball bearings will expand when they hit this groove causing it to mate with the coupling.

- Pressure Plate
    - This piece in its simplest form is a ring. The ring is has three holes in it that will be threaded to hold 1/10” screws. The ring is placed on top of the wide spring and both are placed inside the male side of the coupling. The screws act as pins and travel along a slit cut into the coupling to keep the plate from rotating. The main purpose of this piece is to compress when the male end is inserted and expand when the male end reaches the end of the track; thus, holding the male end in place.
- Ball Bearing Retention Ring
    - This piece is the outer ring that holds the ball bearings in place on the female end. It has six chamfered holes that allow the ball bearings to extrude out from the surface. The smaller holes are for setscrews. The setscrews will secure the ring onto the female end and ensure that the ball bearings do not fall out.
- Leash Ring
    - The leash ring is a constraint requirement. Its function is to allow the attachment of a leash to our separation connector. This ring is attached to the female end of the separation connector in this design as seen in figure 1. Its primary use is to avoid separation by pulling on the cables.

2.3 Minor Pieces

- Wide Spring
    - This spring is for the pressure plate. It will have a wide inner diameter that will fit inside of the coupling on the male end. The spring will contract when the plate applies pressure to it and expand when the male end reaches the end of its track; thus, holding the male en in place. This piece will be purchased from a catalog
- Ball Bearings
    - There are six steel ball bearings. Each ball bearing will have a diameter of .1”. They will be purchased from a catalog. The ball bearing will be held to the female end with help from the ball bearing retention ring. Behind

each ball bearing, there will be a small spring to allow the ball bearing to retract into the female end when a force is applied to it. The ball bearings expand when the force is no longer being applied. For example, in our design the ball bearing retracts when the female end is forced into the coupling and expands when it reaches the inner groove of the coupling; causing them to be mate.

- Ball Bearing Springs
  - There are six small springs. These springs sit behind the ball bearings on the female end. They allow the ball bearings to expand and contract when forces are applied and removed from them.
- Leash
  - The leash is a simple wire cord that is attached to the leash ring on the separation connector. It is used in union with a lanyard which is attached to a launch pad or the side of a stage (of a rocket) that is going to be separating. As a stage separates, it generates the pull force required to separate the two ends of the separation connector. This pull force is applied to the leash, allowing the female end to be pulled away from the male end of the connector.

3. Manufacturing

3.1 Materials

Our initial prototypes are to be made of ABS plastic. We chose this material to begin prototyping because it is a cheap alternative to making a metal prototype. Once our dimensions are finalized and improvements made, we will produce our actual working prototype out of Aluminum alloy 6061-T6. The stainless steel ball bearings and springs were chosen for our prototype because of their low cost and corrosion resistance.

3.2 Component Manufacturing

The compressions springs and ball bearings will be purchased from Century Spring Corporation and Bal-Tec of Micro-Surfacing Engineering Incorporated, respectively. The ball bearing supplier was chosen for their precision and accuracy of producing the bearing ball to one-millionth of an inch, as well as for being associated with the Anti-Friction

Bearing Manufacturers Association (AFBMA). This association uses military specifications, which are compliant with our project requirements.

To begin our prototyping phase, we will first produce a 3-D model, or Fused Deposition Model (FDM), made of ABS plastic. Using FDM samples to test our design will ensure correct dimensions and allows for adjustments and improvements to be made in a cost-effective manner. The ABS plastic was chosen because of its impact resistance and toughness. Each prototype will be tested and improved up to three times before the final prototype is manufactured. The final prototype will be made of Aluminum 6061-T6. This process involves the use of a 3-D SolidWorks model file and a 4-axis Computer Numerical Control (CNC) mill to create a working prototype. Initially, an outside machining company was sought out for our final prototype manufacturing. However, the coupling section of the design increased the price quote.

4. Future Analysis

After our FDM prototype is complete, it will be tested to ensure that it meets the customer's requirements. Our design must withstand and successfully complete at least fifty consecutive connections and separations. The tests to be performed include: vibration, tension, torsion, and drop tests. The Aluminum prototype will be produced and tested once we have created a successful FDM prototype.

5. Project Plan

This section contains our updated Gantt chart. The Gantt chart shows the deadlines we need to meet as well as deliverables that have already been completed. This schedule is tentative and is subject to change. See figure 2 below for updated Gantt chart. (Updated 02/01/2012)

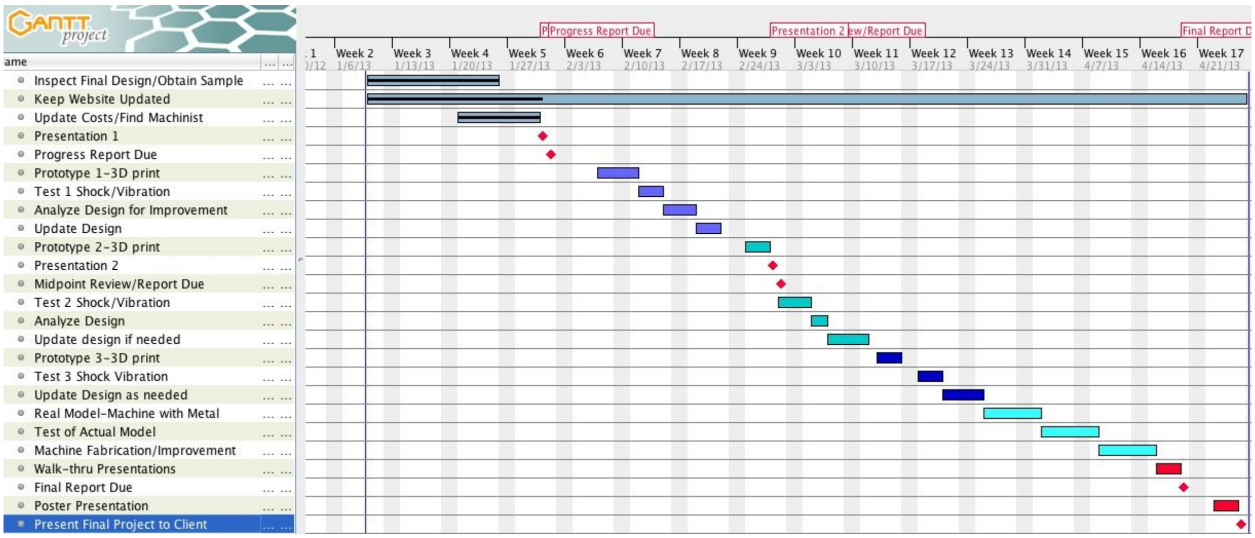

Figure 3: Updated Gantt Chart

6. Conclusion

Our first prototype is scheduled to be printed by February 10, 2013. The feasibility of final prototype being successful depends on how well we manufacture, modify, and test our first plastic prototypes. After our preliminary prototype is made, we will modify our design as needed until the design is ready to make a working, metal prototype. We project that our first metal prototype will be ready by March 31, 2013.

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