Orbital Test Stand

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Engineering Analysis and Design Selection
Document

Submitted towards partial fulfillment of the requirements for
Mechanical Engineering Design I – Fall 2014

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1.0 INTRODUCTION

In order to make the jump from concept generation to final design selection, we must first narrow the project's focus to two or three designs that we wish to examine further. This intermediary step between concepts and final designs exists so that strong cases can be made for only a few designs (rather than weak cases for many designs) before ultimately proceeding with one final design concept. The purpose of this report is to present the cases for the two designs we felt were the most promising for completing the objective of the Orbital Test Stand project. Recalling that we had ten design concepts initially, we had to come to an agreement on the two designs we wanted to include in this report. The consensus for the two designs was based largely on instinct (whether or not we thought the design would work), but we also discussed each design with our contacts at Orbital. The two concepts that we proceed with in this report are the "Winch" design and the "Interior Wheels" design. In the descriptions below for each design, there is a brief introduction, a picture of the design as it was originally sketched by the team, and an overview of the components included in the concept.

2.0 WINCH DESIGN

The winch design calls for the mounting of two winches on opposite sides of the test stand and then using them in conjunction to rotate the test stand 360 degrees in either direction. We have selected a winch that can support the static and dynamic loads of the 5400 lb. rotating ring when loaded with either of the two 600 lb. launch vehicle fairings. We also describe the various mounting strategies for the design, whether it be mounting the winch cable to the rotating ring, or mounting the winch to the floor. The descriptions here are kept relatively brief so that we can discuss further with Orbital on our site visit.

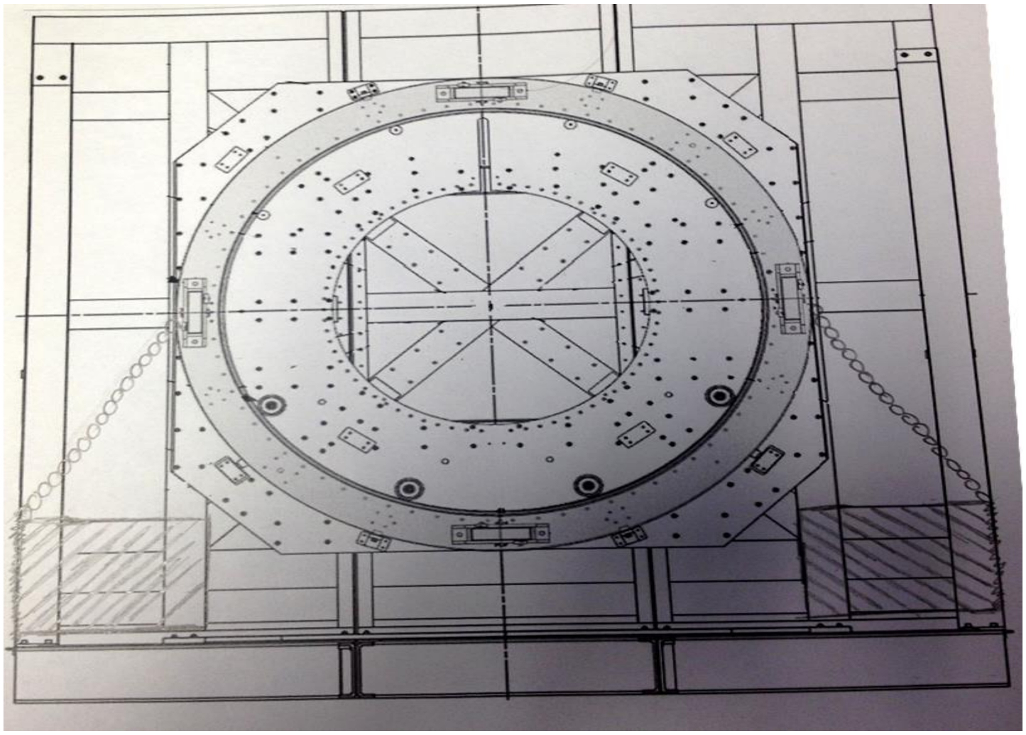

Figure 1

2.1 Ramsay Patriot Winch

Figure 2

Our calculations for the winch indicated a minimum load rating of 8 kip, with 10+ being preferred. We need our winch to have 141 feet of cable length, as well as be electrically powered with a two-way motor, and provide at least 82,620 lbf-in of torque. Examining consumer winches led us to the Ramsay Patriot winch, rated for 15 kips. This winch is an electric, remote controlled two-way winch that comes with 90 feet of 7/16th cable. This cable length will need to be modified to increase to the required 141 feet. Also, this winch runs on a 5.5 Hp motor and provides 1,733,160 lbf-in of torque, for a factor of safety of 21 against a single winch supporting the maximum load that the structure can exhibit on the winch. These winches cost USD 1800 each, and two would be required.

2.2 Mounting Bracket

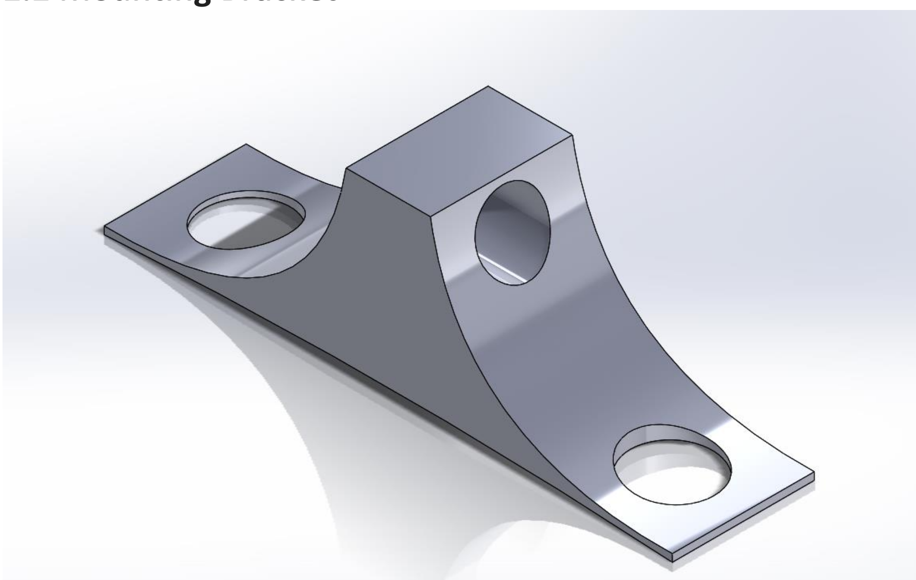

Figure 3

This mounting bracket will mount on the outer diameter of the rotating ring and depending on FEA analysis, either it will be bolted on or welded on; whichever is stronger. The winch cable will go through the hole at the top and that is how the winch will connect to the ring, allowing for the rotation of the fairings.

2.3 Braking/Locking System

Figure 4

As a rough mockup of the braking and locking device, we have a concrete block shown with a pneumatic scissor jack on top as the black and red device. This jack will raise a high friction piece of rubber up and eventually press it against the steel ring surface, providing heavy contact friction to slow the rotation of the ring when it is in motion, as well as act as a locking device when the pieces need to be fixed in a specific location or angle.

2.4 Floor Mounting

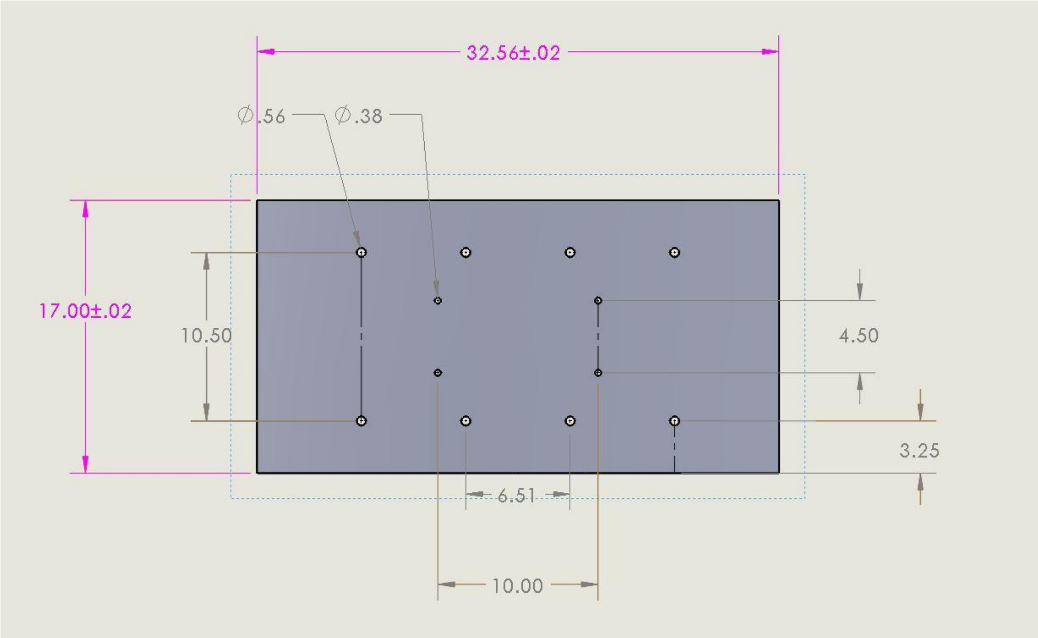

Figure 5

This mock up of the steel plate is a ½ inch thick steel plate. The 4 holes in the center are where the winch will mount down onto the plate, and then the 8 larger holes are where the plate will connect to the floor of the testing bay. Bolts will be selected so that the bolts that are holding the plate down to the floor will shear before the bolts holding down the winch. We designed it to be like this because losing 1 of 8 bolts is significantly less than losing 1 of 4 bolts. Also, if a bolt holding down the winch shears, it could damage the winch and cause the winch to have to be replaced at great cost when compared to just replacing one bolt.

3.0 INTERIOR WHEELS

The interior wheels design calls for the mounting of two pneumatic wheels or heavy duty rollers opposite each other on the inside of the test stand, and then driving them with a motor. The wheels are positioned in such a way so that they create contact friction between the wheel surface and the inner surface of the rotating ring. Since the wheels (or rollers) will be driven by a motor, the key to this design is creating enough contact friction so that the motor facilitates ring rotation and does not result in the tires spinning freely.

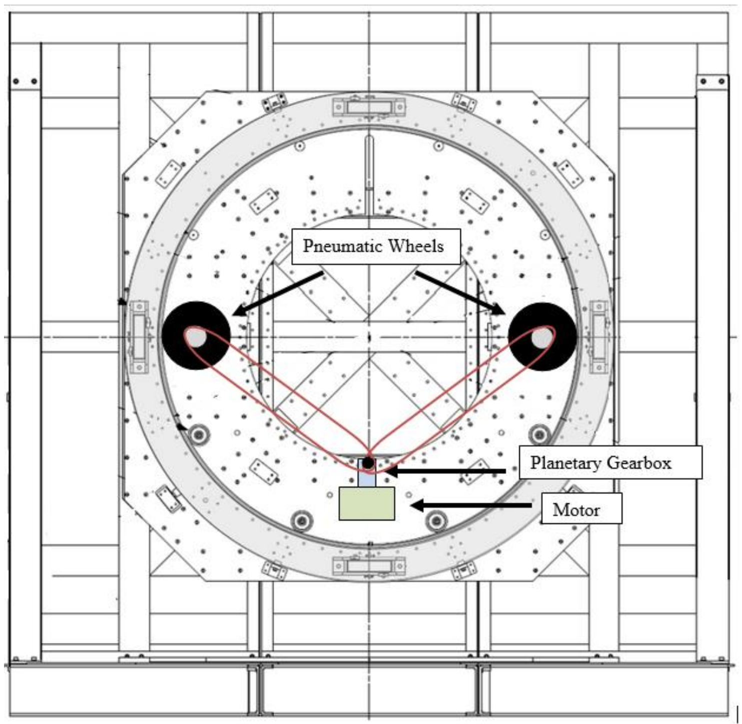

Figure 6

3.1 Motor

The motor needs to provide enough power so that sufficient torque can be applied to the wheels and be reversible. Reliability is a large factor in any engineering design and is especially true for this concept since the motors prevent unwanted rotation of the ring. An electric motor would work best in an indoor environment due to the hazard of fumes expelled by a gas engine. Anaheim Automation was selected to provide the motor for the design due to their product meeting the needs for the project.

Figure 7

3.2 Gearbox

For the selected motor, we needed to select a speed reducer in order to maintain the Test Ring output at 1 rpm. Based on a wheel diameter ranging from 12in to 16in the wheel needs to rotate between 11rpm and 8rpm respectively. For an application with high weight and torque the gearbox needs to withstand those loads. Initially a worm gear box was selected but did not meet the requirement for ±360°. A planetary gearbox was then selected as a final choice as use in our design. Figure 1 below is a gearbox supplied by Anaheim Automation.

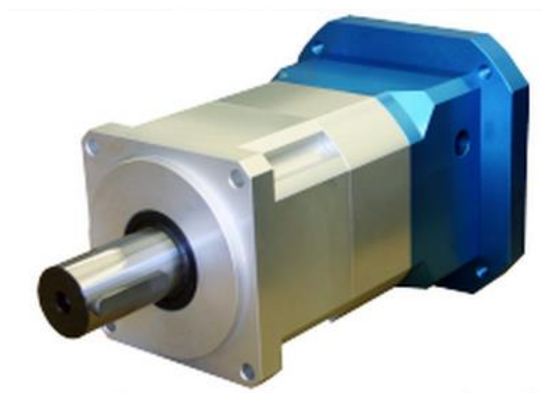

Figure 8

This gearbox comes as a series allowing for a range on gear ratios. The selected gearbox has a 70:1 gear ratio and a maximum output torque of 31456 lb-in. The benefits of this gearbox alongside with its high torque and weight ratio, it is compact and has a greater stability with a low backlash of 10arcmin.
Figure 2 and Table 1 are the overall dimension and specification for the selected planetary gearbox. The given dimension will not take up much space and the preexisting mounting holes allow for easy integration.

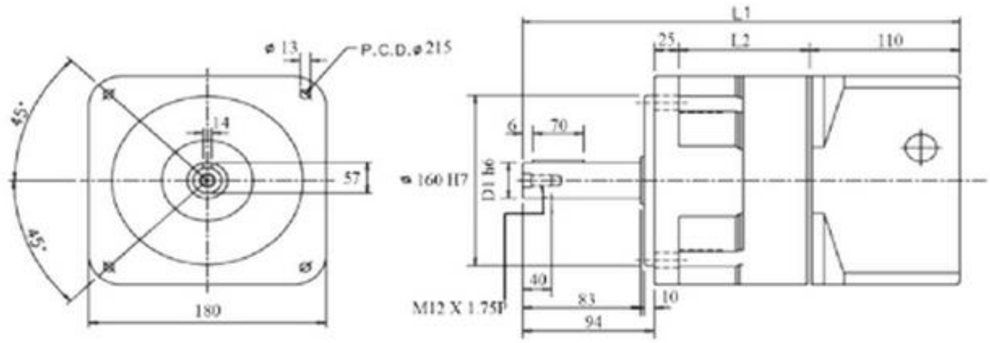

Figure 9

Table 1

Radial Load (lbf)	4946	Axial Load (lbf)	4496
Operating Temp (°C)	-15 – 90	Noise Level (dB)	64
Efficiency	3~10:≥97; 12~100:≥94	IP Rating	IP65

3.3 Wheels

Two tread-free options were investigated for the wheels portion of the design. Option 1 involves the use of heavy duty rollers which were selected for their durability, high load capacity of 1,000 lbf, and their relatively low cost USD 127. In order to achieve the necessary contact and friction forces the wheels would need to be mounted in conjunction with a tensioning mechanism to vary the normal force of the wheel on the frame. Option 2 involves the use of pneumatic slick tires which were selected for their low cost and ease in mounting. The pneumatic tires could be mounted with the center of the hub less than 1 radius from the surface of the ring. As pressure is added the wheel presses against the ring- conforming to the surface- and creates the necessary contact force needed as governed by the equation F=P*A where P is the tire pressure and A is the contact area between the tire and ring.

3.4 Mounting

An adapter plate would be manufactured to allow mounting of the motors, gearboxes, and wheels onto the test stand using pre-existing bolt holes thus minimizing the amount of modifications required. The wheels would be mounted onto a spindle which would in turn be mounted onto the adapter plate. The motors and gearboxes can be bolted directly onto the adapter plate.

4.0 CONCLUSION

Having presented the cases for both designs, we ultimately concluded that proceeding with the winch as a final design concept would be the best course of action for us and for Orbital given the nature of wanting to achieve the objective at minimal cost and minimal modifications. Leading us to this conclusion was the belief that a winch-driven system is a design that we feel like can actually work. We were in agreement that a winch design was one that could be implemented given the time sensitivity of the project. Also driving this conclusion for the winch design is the availability of off-the-shelf components. With the winch design, the largest cost--excluding technical labor for installation--would be the initial purchasing of the winch and that comes at a one-time cost from the manufacturer. We felt like there were just too many unknowns with respect to the interior wheels design and it was difficult to predict the cost of components even when it was at a ballpark estimate. Also, there would be a familiarity for Orbital engineers with the winch design because they are using a similar design--albeit on a much smaller scale--at another location in the testing facility. Finally, the two concepts were both well received by Orbital but in the end they too agreed that the winch design was the best to proceed with as a final design concept.