Nose Cone for Orbital Rocket

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Introduction

Satellites are very fragile and only designed to operate in the vacuum of space. The nose cone, or fairing, protects the satellite from aerodynamic forces encountered during ascent and from heating due to friction with the atmosphere. The nose cone needs to be strong but also light. A heavy nose cone reduces the mass of the satellite that can be launched since 90% of the mass of a rocket is propellant, 5% the satellite and only the remaining 5% is the rocket itself. While going through the atmosphere, the nose cone decreases drag. It separates from the rocket and exposes the satellite once it reaches beyond the atmosphere, approximately 100 km in altitude. There are very few nose cone manufacturers in the world. Manufacturing in-house allows vertical integration and product customization. Reaction Dynamics, a Montreal-based aerospace company, will use the nose cone for its orbital rocket.

Project Description

Design a flight-weight nose cone with a diameter of 110 cm and a height of 130 cm. Choose the alloy that offers the best combination of weight, strength, manufacturability and cost. Using finite element analysis, determine the amount of deformation caused by aerodynamic pressure during ascent. Develop a manufacturing plan optimized for low volume production, either outsourced or by purchasing the required machine tools. Identify manufacturing methods, machine tools costs, and raw material. Identify the risks associated with your design and its production. Plan prototypes to reduce these risks. This could take the form of a smaller nose cone, a section of the full-scale nose cone or test pieces to demonstrate specific features or methods. Once your design is complete, use CFD to determine the aerodynamic losses of your nose cone compared to a commercially available one.

Figure 1 shows the shape of the nose cone for this project. Figures 2 and 3 below show examples of existing nose cones with similar diameters to the one you will be designing.

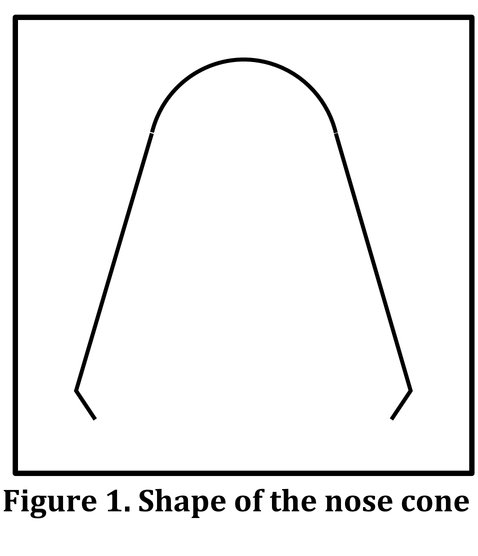

Figure 1. Shape of the nose cone

Figure 2. Composite nose cone, diameter of 1,2 meter. New Zealand.

Figure 3. Rocket with a 1,1 meter aluminum nose cone. Alaska.

The nose cone resulting from this project will not have all the features required of an operational product. It will lack the mechanism to separate the nose in two parts and fall away from the rocket. The nose cone will also lack protective insulation. These features are too complex to design and test for a student project. To simplify your calculations, neglect any temperature effects and assume an ambient surface temperature.

The nose cone will be used on the ground to demonstrate structural integrity and manufacturability but it may also be used for the rocket's initial flight. The first launch of a rocket will often only have instrumentation on board, but no satellite or the need to separate.

Existing nose cones can be up to 17 meters tall, 5 meters in diameter and weigh 1500 kg. These are typically made out of composite and are used by large launch vehicles around the world. Smaller nose cones can be made of aluminum, using an isogrid or skin-and-stringer design.

Expected outcome

- CAD model of the nose cone
- Finite Element Analysis to determine nose cone deformation
- Computational Fluid Dynamics to determine aerodynamic losses
- Manufacturing plan
- Test plan
- Risk reduction activities

Resources

A weekly meeting is recommended for the students to provide an update on their recent progress. These meetings can take the form of mini-reviews to resolve outstanding issues and help eliminate any roadblocks. Students are encouraged to create a simple Gantt chart to facilitate project planning and tracking.

Requirements

It is essential to meet structural requirements to avoid catastrophic failures and loss of mission. The most significant force on the nose cone is the maximum aerodynamic pressure, or MaxQ, which is exerted by the atmosphere on the capsule during ascent. Another force is the differential pressure between the inside of the nose cone and the outside. Typically, the air inside vents during ascent but in an anomaly, some air can stay trapped inside. For these situations, it is valuable to know how much differential pressure the nose cone can withstand without damage.

It is preferable to keep the mass under 150 kg to maximize the payload. Greater flexibility is possible if there is a plan to reduce mass in a future version. Cost can be traded for mass, especially if the mass is already near the target of 150 kg.