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International Journal of Aeronautical Science & Aerospace Research (IJASAR)
ISSN 2470-4415

Design and Analysis of 3/4 Power Series Rocket Nosecone

Research Article

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Abstract

Drag is defined as the force that opposes forward motion through the atmosphere and is parallel to the direction of the free stream velocity of the airflow, this paper included within different types of drag forces some of them are experienced in rocket nosecone like form drag and skin friction drag also supersonic rocket experience additional drag is called wave drag, finally reach on the conclusion that the length of nosecone 3.02976830 meter and total drag force experienced on nosecone 44,987.43173 $kg\ m/sec^2$.

Keywords: Nosecone; Wave Drags; Skin Friction Drags; Form Drags; Induced Drags.

Introduction

In aerodynamics, drag is defined as the force that opposes forward motion through the atmosphere and is parallel to the direction of the free stream velocity of the airflow. Drag must be overcome by thrust in order to achieves forward motion [1]. Form drags,Form or pressure drag is cause by the air that is flowing over the aircraft or airfoil. The separation of air creates turbulence and results in pockets of low and high pressure that leaves a wake behind the airplane or airfoil (thus the name pressure drags) this opposes forward motion and is a component of the total drag. Since this drag is due to the shape or form of the aircraft, it is also called form drag. Streamlining the aircraft will reduce form drag. Skin friction drag,skin friction drag is caused by the actual contact of the air particles against the aircraft. This is the same as the friction between any two objects or substances. Because skin friction drag is an interaction between a solid (the airplane surface) and a gas (the air), the magnitude of skin friction drag depends on the properties of both the solid and the gas. For the solid airplane, skin friction drag can be reduced and airspeed can be increased somewhat by keeping an aircraft's surface highly polished and clean.Wave drag,wave drag is a drag, that retards the forward movement of an airplane, in both supersonic and transonic flight, as a consequence of the formation of shock waves.

Materials and Methods

Given the problem of the aerodynamic design of the nose cone section of any vehicle or body meant to travel through a compressible fluid medium (such as a rocket or aircraft, missile or bullet), an important problem is the determination of the nose cone geometrical shape for optimum performance [2]. The amount of air resistance (drag) that opposes a rocket's motion depends mainly on the shape of the nose cone, the diameter of the rocket and the speed of the rocket. The first point that meets the air is the nose cone at the front end of the rocket. If the speed of a rocket is less than the speed of sound, the best shape of a nose cone is a rounded curve and at supersonic speeds (faster than the speed of sound), the best shape is a narrower and sharper point. Rockets with a larger diameter have more drag because there is more air being pushed out of the way, making a rocket as narrow as possible is the best way to reduce drag also the speed of a rocket through the air similarly increases drag. As speed doubles, drag increases four times as much [3].

Drag force due to shock wave

Wave-drag is induced by the nosecone, and as such, nosecones are designed in order to bring down the drag force on the rocket during flight. The magnitude of nosecone wave-drag is dictated

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Received: July 15, 2020
Accepted: August 09, 2020
Published: August 11, 2020

Citation: Gedlu Solomon. Design and Analysis of 3/4 Power Series Rocket Nosecone. *Int J Aeronautics Aerospace Res.* 2020;7(3):230-234.
doi: http://dx.doi.org/10.19070/2470-4415-2000028

by not only its shape but also by the rocket's velocity and fineness ratio, which is the ratio of a nosecone length to its largest diameter [5]. There are many characteristic nosecone shapes which a modern rocket nosecone may be modeled after namely the cone, tangent ogive, ellipsoid, parabolic, power 0.5 and power 0.75.

As seen in figure 6.1 power 0.75 nosecone shape: at Mach number [0 to 1] nosecone drag coefficient insignificant, Mach number [1 to 1.5] nosecone drag coefficient relatively average, Mach number [1.5 to 6) best.let's take as base diameter of D = 0.605953662 m.

fineness ratio = L/D ------ (1)

L= 3.02976831 m

Configuration of ¾ Power series Nosecone

The Power Series includes the shape commonly referred to as a 'parabolic' nose cone, but the shape correctly known as a parabolic nose cone is a member of the Parabolic Series, and is something completely different. The Power Series shape is characterized by its (usually) blunt tip, and by the fact that its base is not tangent to the body tube. There is always a discontinuity at the nose cone/body joint that looks distinctly non-aerodynamic. The shape can be modified at the base to smooth out this discontinuity. Both a flat-faced cylinder and a cone are shapes that are members of the Power Series. The Power series nose shape is generated by rotating a parabola about its axis. The base of the nose cone is parallel to the latus rectum of the parabola, and the factor n controls the 'bluntness' of the shape. As n decreases towards zero, the Power Series nose shape becomes increasingly blunt. At values of n above about 0.7, the tip becomes sharp [2].

$y = R * (X/L)^n$ ------ (2)

n = 0.75 for a 3/4 power

$A = \pi^* r^2$ ------ (3)

A= 0.288236174 m^2 ----- (4)

$$F_D = C_d * \frac{\rho V^2}{2} * A \text{ ------ (5)}$$

F_D = 10,752.45173 $kg\ m/sec^2$ (newton)

Where

F_D = is the drag force
C_d = is the drag coefficient
A = is the reference area
ρ = is the density of the fluid
V = is the flow velocity relative to the object

Drag force due to skin friction

Reynolds number, Reynolds number is a dimensionless value that measures the ratio of inertial force to viscous force and describes the degree of laminar or turbulent flow. Systems that operate at the same Reynolds number will have the same flow characteristics even if the fluid, speed and characteristics length vary.

$$Re = \frac{\rho * V * L}{\upsilon}$$

Re = 289,748,110.2

Where

V = fluid velocity (m/s)
L = characteristics length, the chord width of an airfoil (m)

Figure 1. Wave drag coefficient for different nose cone shapes (fineness ratio is 5:1) [4].

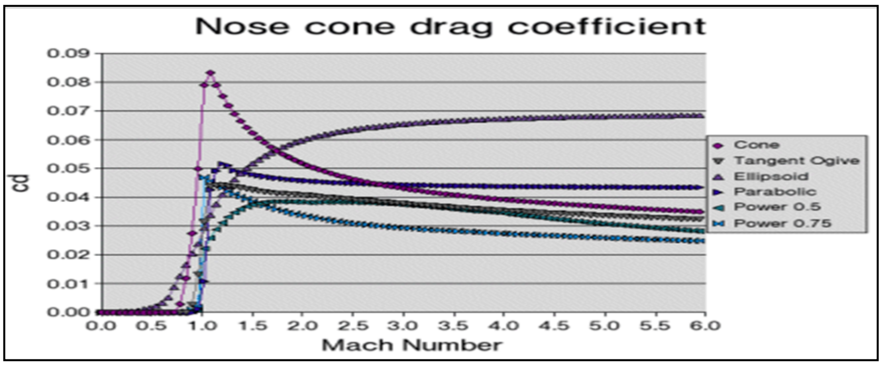
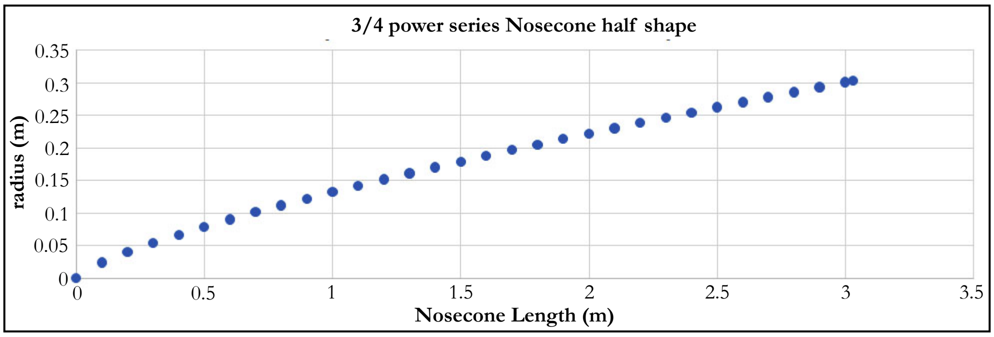


Figure 2. Nosecone Length Vs Nosecone radius.



ϱ =fluid density (kg/m^3)
υ = fluid dynamic viscosity (kg/m.s)

Let consider the body is flat plane

$$F_f = C_f * \frac{\rho V^2}{2} * A \text{ ------- (6)}$$

but
C_f = Skin friction coefficientand from figure 6.8, C_f = 0.002

$A_1 = L * C$ ---- (7)
A_1 = 3.76140353 m^2
$A_2 = \pi * r * hs$ ---- (8)
A_2= 2.944542314 m^2
$A = A_1 + A_2$ ----- (9)
A= 6.705945844 m^2

$$F_f = 6,291.74 \frac{kg\ m}{\sec^2} \text{ (newton)}$$

Drag force due to pressure

Let consider the body is long cylinder

$$F_p = C_p * \frac{\rho V^2}{2} * A \text{ ----- (10)}$$

$A = \pi r^2$ ----- (11)
A= 0.297828147 m^2

$$F_p = 27,943.24 \frac{kg\ m}{\sec^2} \text{ (newton)}$$

Nosecone material, Fiber Glass

A fiberglass is a form of fiber-reinforced plastic where glass fiber is the reinforced plastic. This is the reason perhaps why fiberglass is also known as glass reinforced plastic or glass fiber reinforced plastic. The glass fiber is usually flattened into a sheet, randomly arranged or woven into a fabric. According to the use of the fiberglass, the glass fibers can be made of different types of glass. Fiberglass is lightweight, strong and less brittle. The best part of fiberglass is its ability to get molded into various complex shapes. This pretty much explains why fiberglass is widely used in bathtubs, boats, aircraft, roofing, and other applications [8].

Depending on the raw materials used and their proportions to make fiberglass, fiberglass can be classified into following major types:

• A-glass, is also called as alkali glass and is resistant to chemicals. Due to the composition of A glass fiber, it is close to window glass. In some parts of the world, it is used to make process equipment.
• C-glass, offers very good resistance to chemical impact and is also called as chemical glass.
• E-glass,it is also called as electrical glass and is a very good insulator of electricity.
• AE-glass,this is alkali resistant glass.
• S glass,it is also called as structural glass and is known for its mechanical properties.

Nosecone Wall Thickness

Fiberglass fabrics will not stretch or shrink. Nominal elongation break is 3-4 percent. The average linear thermal expansion coefficient of "E" glass is 5.4 by 10.6 cm/cm/°C [10].

$$d = \frac{P_a L D}{4E\Delta L}(1-2\nu) \text{ ------(14)}$$

$$p_D = \frac{F_D}{A_D} = 37,304.31049 \text{ pascal}$$

Figure 3. friction coefficient for parallel flow over smooth and rough flat plane [6].

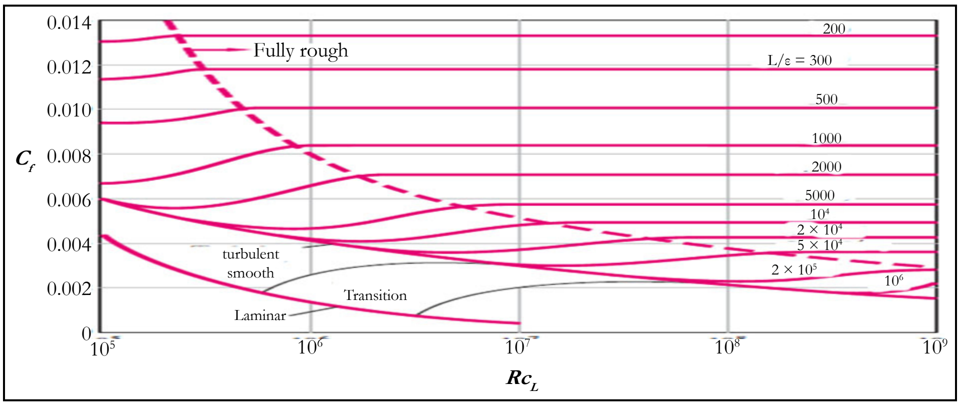


Figure 4. Drag coefficient of blunt nose and round nose cylinder versus fineness ration l/d [7].

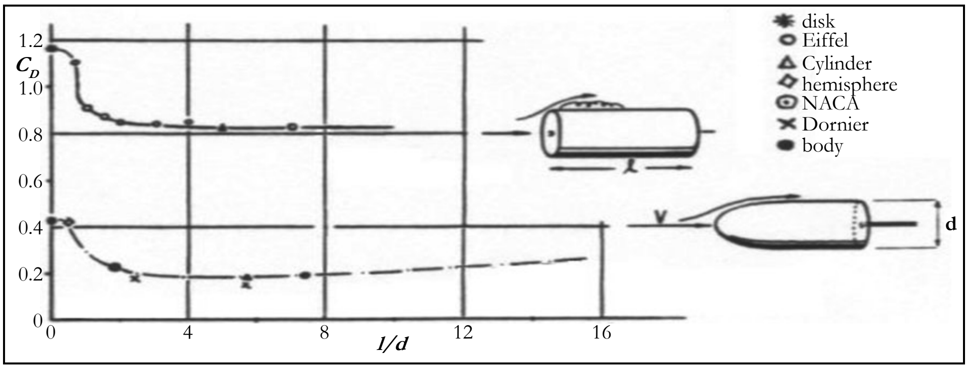
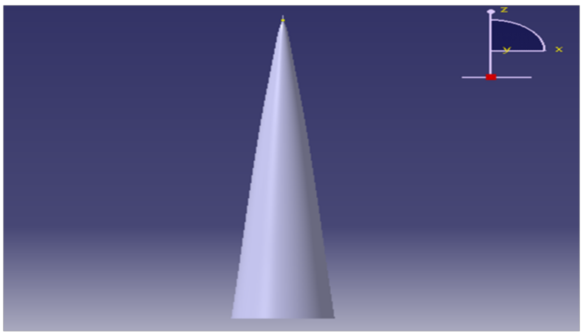


Table 1. S-Glass fiber material with 64% SIO_2, 24%Al_2O_3 and 10% Mgo [9].

Property	Minimum value (S.I.)	Maximum value (S.I.)	Unit (S.I.)
Atomic volume(average)	0.009	0.093	m^3/kmol
density	2.485	2.495	Mg/m^3
Energy content	100	120	MJ/kg
Bulk modulus	51	55	Gpa
Compressive strength	4000	5000	Mpa
ductility	0.052	0.053	
Elastic limit	3750	4085	Mpa
Endurance limit	4050	4410	Mpa
Fracture toughness	0.5	1	$Mpa.m^{1}/2$
Hardness	5000	6000	Mpa
Loss coefficient	$1.00E^{-5}$	0.000	
Modulus of rupture	4500	4900	Mpa
Poisson's ration	0.21	0.23	
Shear modulus	35	39	Gpa
Tensile strength	4700	4800	Mpa
Young's modulus	86	93	Gpa
Glass temperature	920	950	K
Latent heat of fusion			KJ/kg
Maximum service temperature	570	590	k
Melting point			k
Minimum service temperature	0	0	k
Specific heat	735	740	J/kg.k
Thermal conductivity	1.2	1.35	W/m.k
Thermal expansion	2.8	2.95	10-6/k
Breakdown potential	15	20	MV/m
Dielectric constant	5.2	5.34	
Resistivity	3.16E+15	1.00E+16	10^{-8}ohm.m

Figure 5. 3D model for ¾ power series Nosecone.



— = 938.2330467 pascal

$$p_p = \frac{F_p}{A_p} = 93{,}828.36855 \text{ pascal}$$

d = 0.004369576015 mm

take factor of safety 450 and d = 2 mm

$$\Delta D = \frac{P_a D^2}{4Ed}\left(1 - \frac{\upsilon}{2}\right) \quad \text{---- (15)}$$

$\Delta D = 0.047186816$ mm

Results and Discussions

The following conclusion is drawn on nosecone length 3.02976830 meter: drag force due to shock wave 10,752.45173 $kg\ m/sec^2$, drag force due to skin friction 6,291.74 $kg\ m/sec^2$, drag force due to pressure (form drag) 27,943.24 $kg\ m/sec^2$ and Nosecone Wall Thickness 2 mm.

Acknowledgement and Declarations

They author of this paper appreciate Dr. Yeshurun Alemayehu, Director of Space Engineering Research and Development, Ethiopia Space Science and Technology institution, Addis Ababa, Ethiopia for their valuable advice.

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