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DESIGN OF FIBER REINFORCED PLASTIC LAUNCH TUBE

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ABSTRACT

Launch tube is widely used in defense sector to launch the missiles as well as to carry the missiles from one place to another. Use of fiber reinforced plastics reduces the weight of product with out any reduction in the load carrying capacity and stiffness. Because of their the material's high elastic strain energy storage capacity and high strength-to-weight ratio compared with those of steel, fiber reinforced plastics are considered as a materials for construction of launch tubes. Fiber reinforced plastic tubes made of unidirectional carbon fibers embedded in epoxy resin are 65 to70 percent lighter than equivalent steel tubes. Fiber reinforced plastics also exhibit excellent fatigue resistance and durability.

Graphite epoxy composites are widely used in manufacturing launch tubes. Since tubes made of graphite epoxy are often failed at extreme load conditions, there is a continues search for an alternative. In this paper a launch tube is modeled and analyzed for both glass epoxy composites and graphite epoxy composites. The results are tabulated for different orientations of fibers. Both thermal and coupled analyses are carried out. And vonmises stresses are analyzed. Finally it is found that glass epoxy materials possess better properties than graphite epoxy materials and suits well for manufacturing launch tubes.

Key words: Modelling, Analysis, Design, Fiber Reinforced Plastic, Launch Tube

1.0 INTRODUCTION

General purpose of launch tube is to launch the missiles, more over to carry the missiles from one place to another place which are used in defense applications The launch tube contain lugs, the launch lugs are small tubes (Straws), which are attached to the body tube. The launch rail is inserted through these tubes to provide stability to the rocket during launch.

Launch tube is not secured enough inside the launcher, it is pulled out of the launcher and falls back during launching, and the inner part of the launch tube will experience high plume static pressure and plume temperature. Missiles launch from a floating platform. This includes tests of the buoyancy of the launch platform, ease of set-up and use, rate of wind drift, ease of loading missiles into launch tube and erecting on the float gantry, Test of ignition circuits in a wet environment, launch control procedure, and the ability to track and recover missiles. Filament wound launch tubes are just another form of rocket motor cases, with both ends open. Launch tubes employ the same reinforcement materials, design principles, and manufacturing methods.

Launch tubes operate on the same principle as ancient blowgun. A Projectile is inserted into the tube, a gas (air or other) is forced into one end of the tube and the projectile shoots out from the other end.

A General definition of a composite is a synergistic combination of two or more materials, more specifically; the composites referred to here comprise high strength reinforcement in fibrous form, incorporated into and bonded together by matrix, usually a thermosetting polymer. The term fiber reinforced plastics (FRP) is widely used to describe such materials with glass-reinforced plastic (GRP) when the reinforcement is glass fiber. Glass reinforced epoxy (GRE) is used when, as in the case of much composite pipe work, epoxy resin in the matrix.

The use of composite material in the aerospace, rail, marine and civil engineering applications is rapidly increasing. The materials cost economics low weight, high strength and high stiffness, combined with their durability, Means that these materials provide an effective means of achieving design requirements that are driven by consideration weight, Longevity and through life.

1.1 FEA ANALYSIS OF LAUNCH TUBE

Structural analysis is probably the most common application of the finite element method. The term *structural* (or *structure*) implies not only civil engineering structures such as bridges and buildings, but also naval, aeronautical, and mechanical structures such as ship hulls, aircraft bodies, and machine housings, as well as mechanical components such as pistons, machine parts, and tools.

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The seven types of structural analyses available in the ANSYS family of products are explained below. The primary unknowns (nodal degrees of freedom) calculated in a structural analysis are *displacements*. Other quantities, such as strains, stresses, and reaction forces, are then derived from the nodal displacements.

Structural analyses are available in the ANSYS Multiphysics, ANSYS Mechanical, ANSYS Structural, and ANSYS Professional programs only.

You can perform the following types of structural analyses. Each of these analysis types is discussed in detail in this manual.

Static Analysis--Used to determine displacements, stresses, etc. under static loading conditions. Both linear and nonlinear static analyses. Nonlinearities can include plasticity, stress stiffening, large deflection, large strain, hyper elasticity, contact surfaces, and creep.

Modal Analysis--Used to calculate the natural frequencies and mode shapes of a structure. Different mode extraction methods are available.

Harmonic Analysis--Used to determine the response of a structure to harmonically time-varying loads.

Transient Dynamic Analysis--Used to determine the response of a structure to arbitrarily time-varying loads. All nonlinearities mentioned under Static Analysis above are allowed.

Spectrum Analysis--An extension of the modal analysis, used to calculate stresses and strains due to a response spectrum or a PSD input (random vibrations).

Buckling Analysis--Used to calculate the buckling loads and determine the buckling mode shape. Both linear (eigenvalue) buckling and nonlinear buckling analyses are possible.

Explicit Dynamic Analysis--This type of structural analysis is only available in the ANSYS LS-DYNA program. ANSYS LS-DYNA provides an interface to the LS-DYNA explicit finite element program. Explicit dynamic analysis is used to calculate fast solutions for large deformation dynamics and complex contact problems

2.0 MODELING OF LAUNCH TUBE

The modeling of the launch tube was done in CATIA software. This model was transferred to ANSYS software through IGES file format.

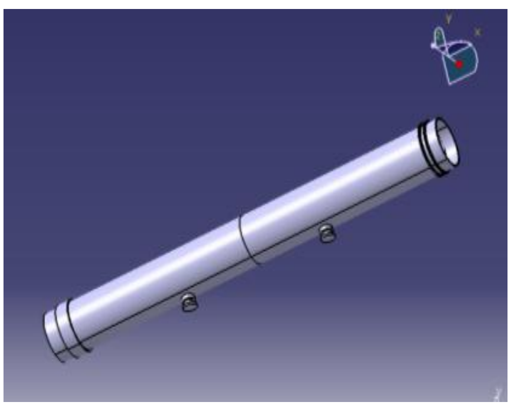


Fig 1: Modeling of the launch tube in CATIA

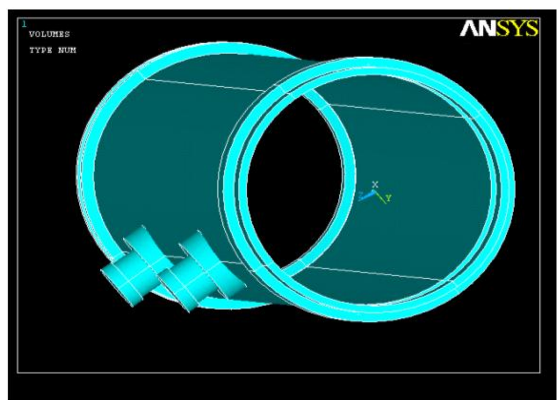


Fig 2: Modeling of the launch tube in ANSYS

2.1 Material Properties

2.1.1 Physical properties of E Glass fiber

Physical property	Metric	Comment
Density	2.54 - 2.6 g/cc	Independent of length& size of tube

2.1.2 Mechanical properties of E Glass fiber

Tensile Strength, Ultimate	3448 MPa	At 23°C (73°F); Virgin strength. 50-75% variation in finished product; 5310 MPa at -190°C (-310°F); 2620 MPa at 370°C (700°F); 1725 MPa at 540°C (1000°F)
Modulus of Elasticity	72.4 GPa	at 23°C (73°F); 72.3 GPa at 540°C (1000°F)
Poisson's Ratio	0.25	Independent
Shear Modulus	30 GPa	Calculated

2.1.3 Thermal properties of E Glass fiber

Physical property	Metric	English	Comment
CTE, linear 20°C	5 µm/m-°C	2.78 µin/in-°F	
CTE, linear 250°C	5.4 µm/m-°C	3 µin/in-°F	from -30 to 250°C (-20 to480°F)
Heat Capacity	0.81 J/g-°C	0.194 BTU/lb-°F	at 23°C (73°F); 1.03 J/g-°C (0.247 Btu/lbf-°F) at 0°C (390°F)
Thermal Conductivity	1.3 W/m-K	9.02 BTU-in/hr-ft²-°F	
Melting Point	Max 1725 °C	Max 3140 °F	

2.1.4 Mechanical properties of graphite fiber

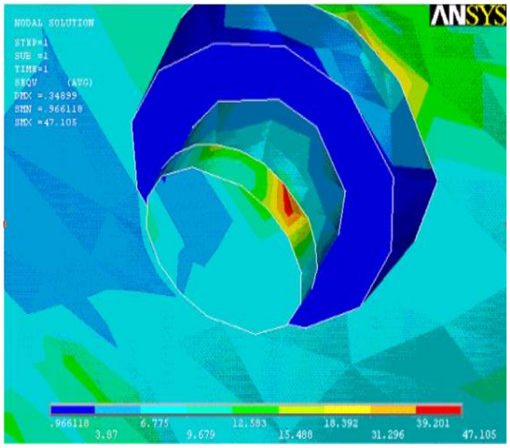
Modulus of elasticity	207 Gpa
Tensile strength	1035 Mpa
Poisson's Ratio	.25
Shear modulus	2.6 Gpa

2.2 Viewing the results in general post processor.

Failure stresses i.e. vonmises stresses have been seen in general post processor by using contour plot option. In this option again by selecting nodal solution option vonmises stresses have been observed. The stress plot of the launch tube, which is having 6mm thickness and having 45^0 layer orientation angles. Is shown as below.

2.2.1 Graphite

Load applied
Radial pressure = 0.33 MPa
Axial pressure = 2.84625 MPa



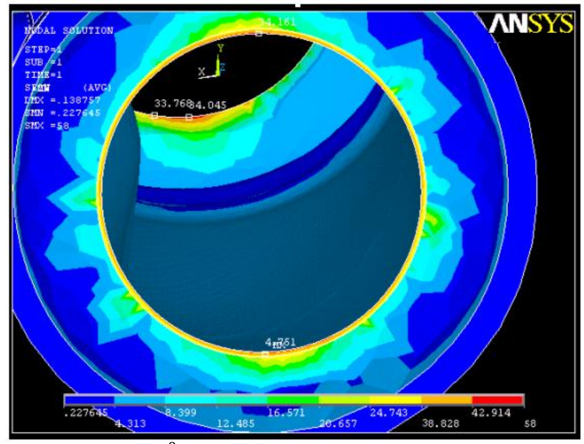
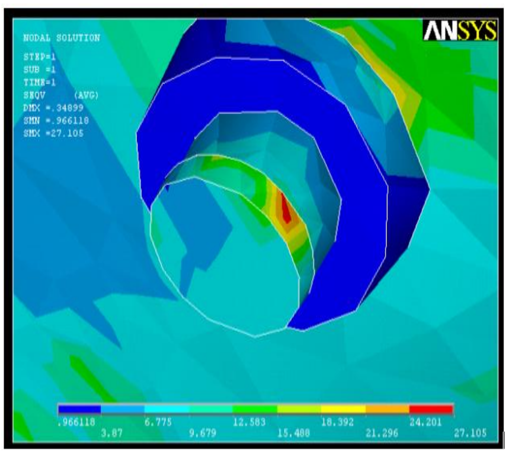


Fig3: Maximum stress plot at mounting lug for 6mm thickness Launch tube having 45^0 orientation angle of graphite fiber

Fig 4: The stresses obtained in theses cases are out of safe limits, so further analysis is done for glass epoxy composite material



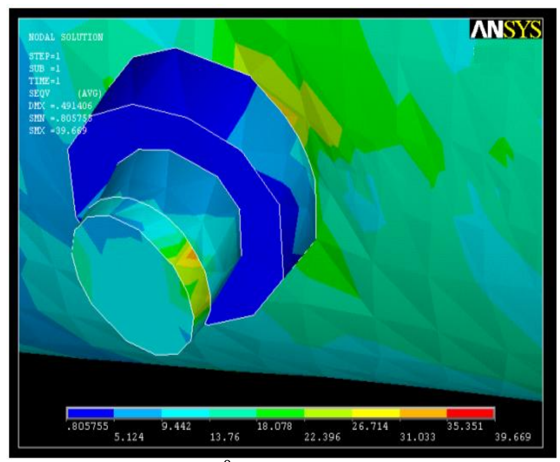


Fig 5: Maximum stress plot at mounting lug for 5mm thickness launch tube having 45^0layer orientation angle

Fig 6 Maximum stress plot at mounting lug for 3mm thickness launch tube having 45^0layer orientation angle

Table showing different values of vonmises stresses for different layer orientation angles.

	Layer Thickness 6 mm	Layer Thickness 5mm	Layer Thickness 4mm	Layer Thickness 3mm
Layer Orientation Angle 15^0	26.594 Mpa	27.415 Mpa	32.024 Mpa	41.025 Mpa
Layer Orientation Angle 30^0	26.421 Mpa	28.174 Mpa	31.246 Mpa	40.348 Mpa
Layer Orientation Angle 45^0	25.695 Mpa	27.105 Mpa	31.371 Mpa	39.669 Mpa
Layer Orientation Angle 60^0	26.097 Mpa	27.184 Mpa	32.338 Mpa	40.554 Mpa
Layer Orientation Angle 75^0	25.998Mpa	27.286Mpa	32.018Mpa	40.024Mpa

By observing the above values in the table low stress values were obtained for 45^0 layer orientation angle for 6mm, 5mm, and 3mm thickness launch tubes. But where as for 4mm thickness launch tube low stress value was obtained for 30^0 layer orientation angle. So 45^0 layer orientation angle is the preferable angle in manufacturing of the launch tubes.

So maximum of 39.669 MPa have been obtained for 3mm thickness launch tube, which is having 45^0 layer orientation angle. By manufacturing the launch tube with 3mm thickness launch tube and with 45^0 layer orientation angle 38% reduction in both weight and cost have been obtained

3.0 RESULTS AND DISCUSSIONS

3.1 Thermal Analysis

Now thermal analysis has been done in order to find out the thermal stresses. Maximum of 85^0C was applied on the inner surface of the launch tube. Figures regarding thermal analysis are shown below. Maximim of 3.508 MPa has been found out which is with in the allowable limit only.

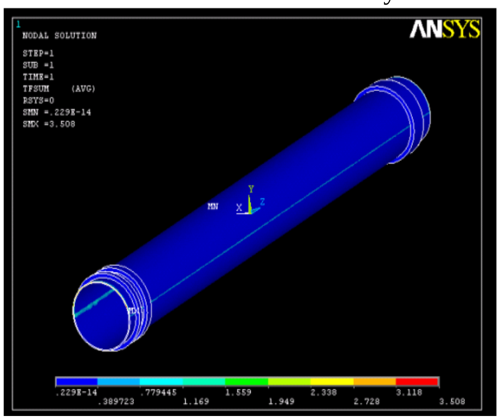


Fig 7: Thermal stress plot of launch tube

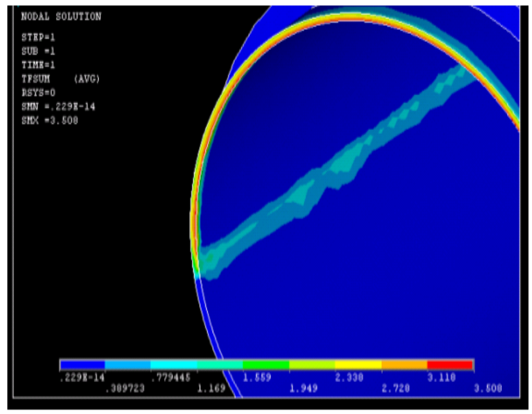


Fig 8: clear representation of thermal stress at side edges of launch tube

3.2 Coupled Field Analysis

Analysis where in the results of one analysis form as input for the other analysis is referred to as coupled field analysis. Due to the complex nature of the physical processes being modeled, it not unusual to conduct coupled analyses as part of a design program. Fluid-structural, fluid-thermal and fluid-acoustic analyses are most common types. Thermal-Structural is the most commonly performed analysis.

Some of the CAE software has the ability to perform the coupled field analysis automatically where as some do not have that capability. However in both cases the Engineer can run one simulation, obtain out put results and apply them as inputs for the other analysis.

The results of thermal analysis were given as input in the coupled field analysis. That is nothing but applying both pressure and temperatures simultaneously. Failure stresses in X, Y and Z directions were found out as 18.516MPa, 2.965MPa and 6.041MPa respectively. Figures of failure stress plots in coupled field analysis are

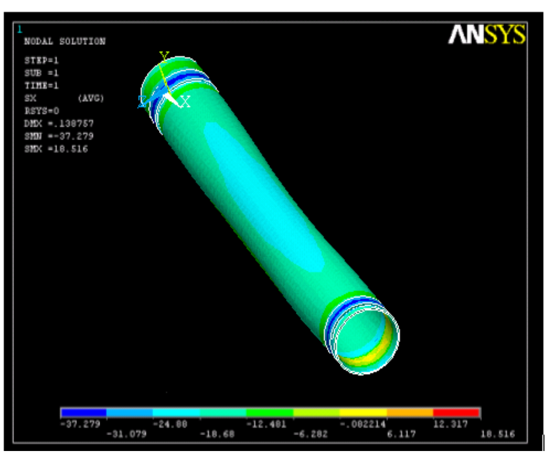


Fig 9: stress plot in coupled field analysis in X direction

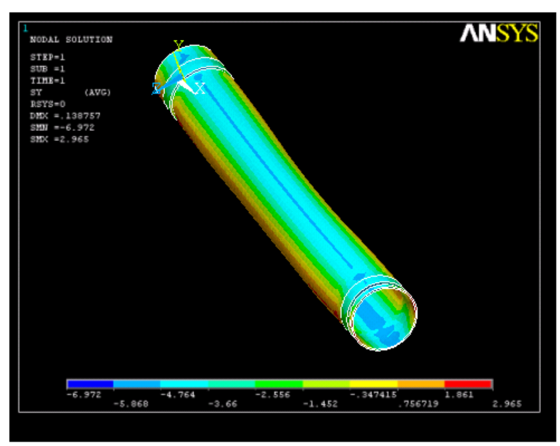


Fig 10: stress plot in y direction in coupled field analysis

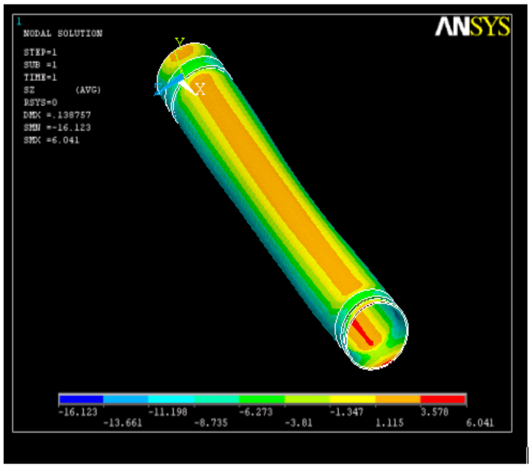


Fig 9.4 stress plot in coupled field analysis in Z direction

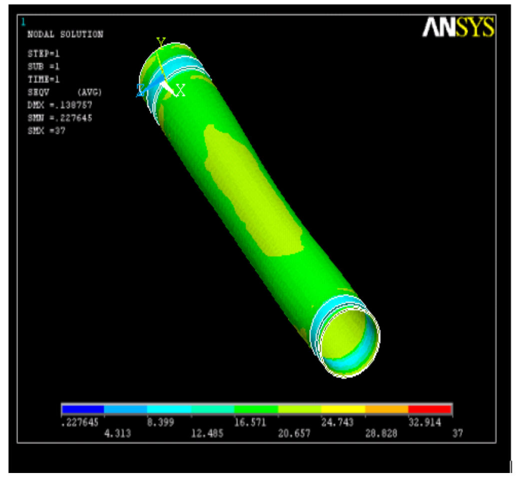


Fig 9.5 vonmises stress plot in coupled field analysis

So obtained maximum vonmises stress is 37 MPa in the coupled field analysis. The design stress limit is 72.426 MPa for the given pressure and temperature .so the design of launch tube which is having 3 mm thickness is the safest design, because the obtained stress value is with in the allowable limit only.

4.0 CONCLUSIONS

(i) Structural Analysis

By observing the values from the results table, low stress values were obtained for 45^0 layer orientation angle for 6mm, 5mm, and 3mm thickness launch tubes. But where as for 4mm thickness launch tube low stress value was obtained for 30^0 layer orientation angle. So 45^0 layer orientation angle is the preferable angle in manufacturing of the launch tubes.

So maximum of 39.669 MPa have been obtained for 3mm thickness launch tube, which is having 45^0 layer orientation angle. But the allowable design stress limit is 72.426MPa.s the obtained stress value is with in the allowable limit only. So manufacturing of the launch tube can be done with minimum amount of material, which leads to low weight and low cost. And more over 38% reductions in weight and cost have been obtained.

(ii) Thermal Analysis

For FRP materials temperature limits for most common applications are 320^0k and for some applications it is up to 340^0k. And for some special cases it is up to 400^0k.in this project applied temperature is 358^0k.The design stress limit for the given temperature is 72.426 MPa, the maximum stress obtained in this thermal analysis is 3.509 Mpa, which is with in the allowable limit only.

(iii) Coupled Field Analysis

For combined temperature and pressure loads the maximum vonmises stress obtained in coupled field analysis = 37 MPa .and the design stress limit is 72.426 MPa for the given pressure and temperature the obtained stress value is with in the allowable stress limit only.

In the above three analyses the obtained stresses are with in the allowable stress limits only. Developed design of launch tube which is having 3 mm thickness in this project can be with stand for the application of combined pressure and temperature loads and more over it can be manufacturability also.

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