Design Optimization of Aircraft Fuel Tank by Finite Element Analysis

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ABSTRACT

An aircraft fuel system may be defined as a system which enables the fuel to be loaded, stored, managed and delivered to the propulsion system of an aircraft. In a modern, multiengine passenger or cargo aircraft, the fuel system is likely to consist of multiple fuel tanks which may be located in the wing, fuselage or both combined. Each tank is equipped with internal fuel pumps and has the associated valves and plumbing to feed the engines. The tanks are made of materials that will not react chemically with any aviation fuel. Aluminum alloy, Synthetic rubber or nylon bladder type fuel tanks are mostly in use. Fuel pressure is acted on the tank walls by the rotation of aircraft and the influence of aerodynamic force and centrifugal force applying on aircraft has been totally considered.

INTRODUCTION

DA42 Twin star light Aircraft was the lightest aircraft in 2006. It has decent cruise speed with comfortable cabin and even economy. It has capacity of 100L fuel storage. It has decent cruise speed and economy. This project is to study about aircraft fuel tank made with metal. Positon, size, and shape of fuel tanks vary with the type of aircraft in which they are installed. They are most often located in the wings. Wing tip tanks are common. But in light aircrafts it is located in fuselage.

Aluminum is a clean, stable and easy to work material that always yields predictable results. Welding aluminum is considered to be an “art”, merely fusing the edges of an aluminum tank results in a weak joint, which might split from vibration, and fluid loads. An Aluminum tank, being a good conductor of electricity, can be easily grounded to the aircraft ground during refueling, thereby eliminating the risk of static electricity build-up. The tank is modeled using 2024 T3 grade Aluminum alloy sheet to sustain higher loads.

1.1 Tank Design Considerations

- Single large tank is easy to make and cost less it also makes more efficient than couple of smaller tanks.
- Avoiding Odd shapes makes us easy to design, fabricate and also insulation is easy
- Try to avoid more complex shapes which will reduce weld zone and simplifies the design

- Baffles are used to minimize the sloshing of fuel in tank during maneuvering. They also strengthen the tank by increasing rigidity in the relatively thin metal.

1.2 METHODOLOGY

The Methodology involves the following steps.

1. Geometric Construction: Creating a model of the tank in Creo and pulling it into ANSYS. Assigning area and volume to the model.
2. Once the model ready need to discretize which involves dividing the continuum system into discrete elements. This is done by dividing the body structure into an equivalent system of smaller bodies or elements
3. Assigning the material properties to the structure like Young's modulus, Poisson's ratio and density.
4. Boundary conditions are applied by constraining the tank on all 3places of bolted location. Later applying pressure from inside the tank.

Once after assigning the boundary conditions static analysis is performed, and later it is analysed to dynamic conditions to understand the response of the tank.

MATERIAL PROPERTIES

Density	2700 Kg/mm2
Tensile Strength, Ultimate	485 Mpa
Tensile Strength, Yield	345 Mpa
Modulus of Elasticity	72.4 Gpa
Poisson's Ratio	0.33

MODELLING AND ANALYSIS

The tank is designed to a capacity of 100liters of fuel. It needs to sustain the pressure of 24kpa. Shape of the tank partly cylindrical and partly rectangular in cross section. A rectangular cross section is maintained for top half portion and semi cylindrical for the bottom portion Using baffles with cut outs at three corrugated regions. Fuel tank is made of 2024-T3 Aluminum alloy sheet with 1mm thickness, and thickness varies to Stiffeners, Gussets and Flanges. The whole tank is mounted using anchor bolts on 3 sides.

Our main aim is to analyze a fuel tank for different inertial load cases as per FAR - 23 in addition to a test pressure of 3.5 psi (24 KPa), to validate whether the design is safe or not.

A static analysis is performed to check the stress and displacements are in the critical components. Even we check whether the structure is safe and under Margin of safety in strength for the given loads.

BOUNDARY CONDITIONS

The fuel tank is mounted on the hat rack provided on three sides in the fuselage, similar flange is provided on the tank along three sides to attach using anchor bolts at 15 points. At bolted joints all translations (u = v = w = 0) are arrested. The boundary conditions are shown in fig 4.9.

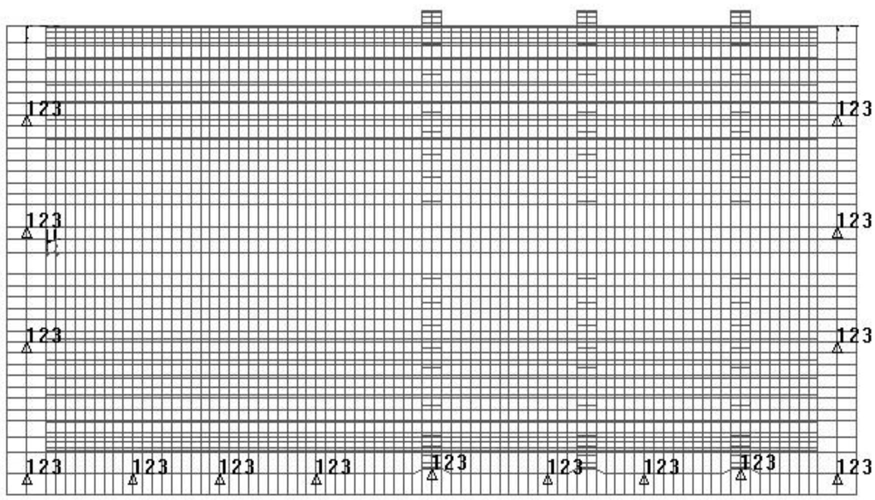


Fig shows boundary conditions

INERTIA DIRECTION	INERTIA FACTOR	CRITICAL COMPONENT
Forward	18.0 g	Forward wall
Sideward	4.5 g	Side wall
Upward	3.0 g	Top wall

Downward	3.8 g	Bottom curved floor

Further we are pressurizing the tank for 24K which developed during maximum ultimate acceleration with full tank, whichever is greater. Because, the supporting structure must be designed for the critical loads occurring in the flight or landing strength conditions combined with the fuel pressure loads resulting from the corresponding accelerations. For this purpose all the fuel tank walls are subjected to a uniform pressure load of 3.5 psi (24 KPa). The schematic diagram of fuel tank with inertia factors in the respective inertia directions is shown below.

TABLE 4.1 Ultimate inertia factors as per FAR - 23

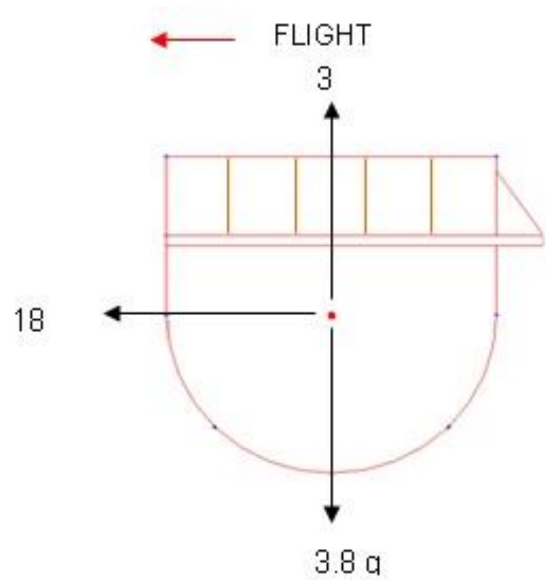
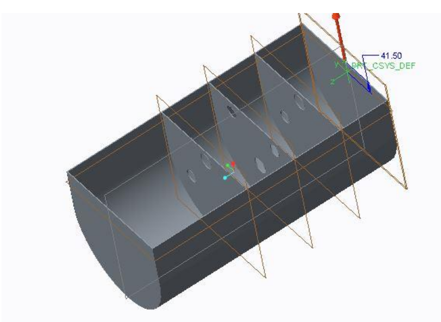


Fig shows fuel tank with inertia factors (view from left hand side)

Modelling and Simulation

A 3-D model is designed using Creo referring the design paper by Bairoju Shiva Kumar. This tank is designed to 100lt capacity for cruise condition.



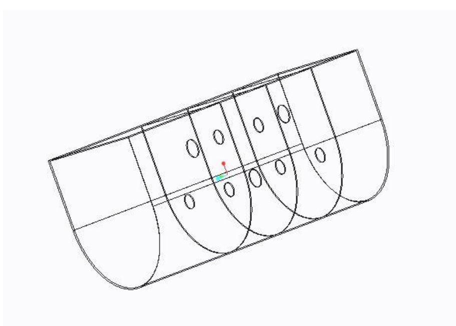
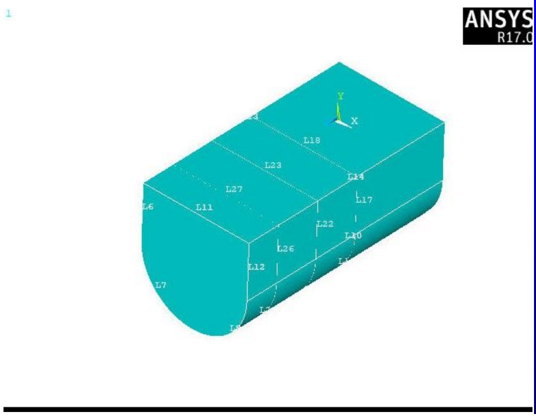
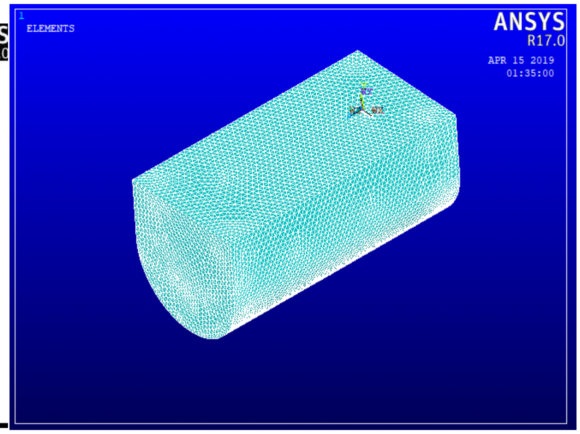


Fig shows the cut section of Cad model   Wireframe model of Aircraft fuel tan

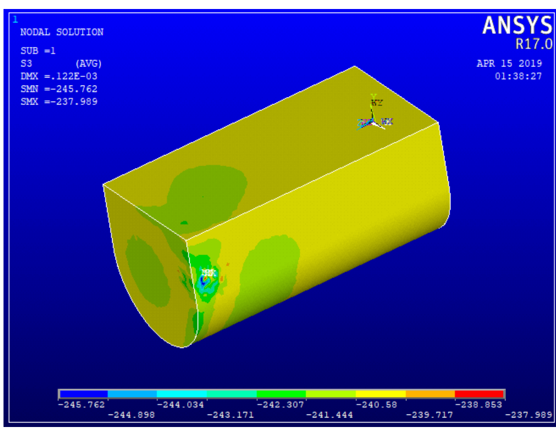


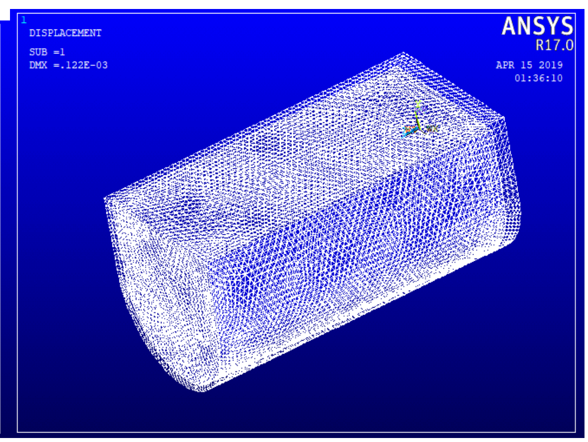


Ansys model   Mesh file

Results and Discussion:

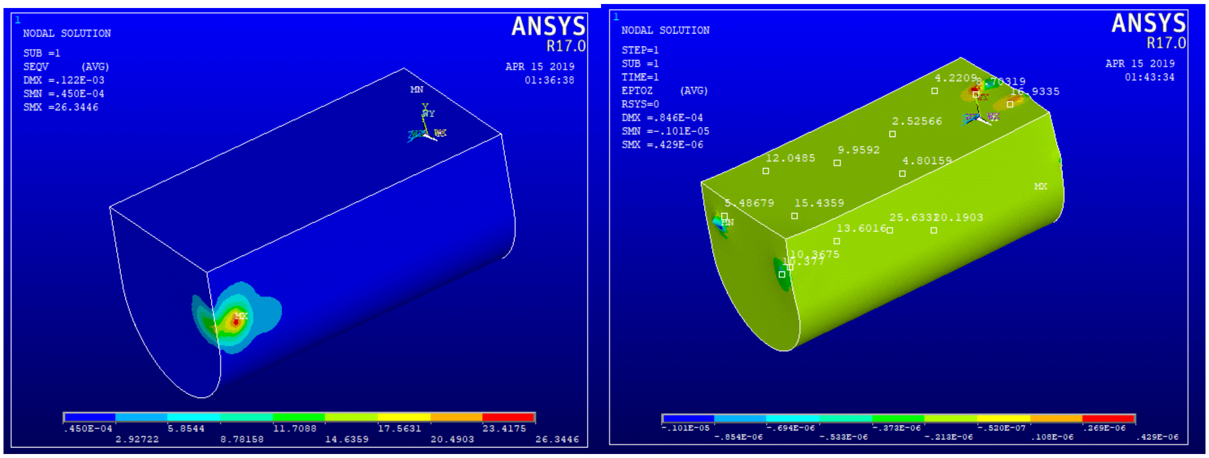
Total deformation was plotted which resulted showing that tank hasent buckeled. So that it states tank is under the load limit.We modeled a DA42 Aircraft fuel tank. Static analysis is performed. In this static analysis we are placing the tank on ground so that initially we can test it on ground conditions. These resulted to plot the values of static analysis during ground conditions. Here we observe that all the stresses are under elastic limit.



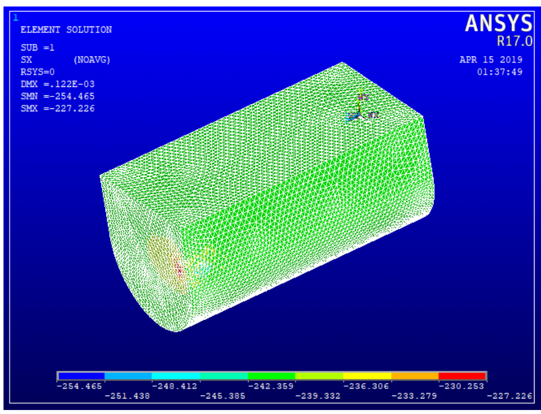


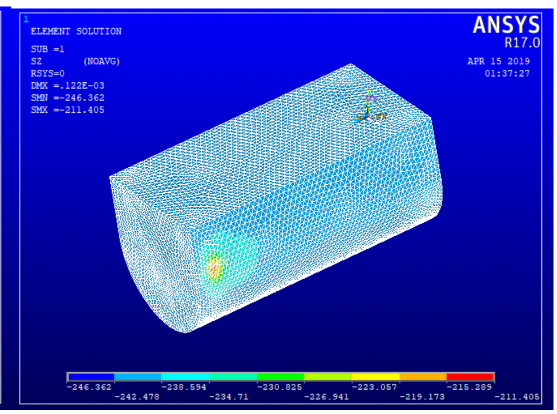
Principle stress in Z-direction

In the fallowing figure results are plotted that they have any fuel tank problem. As the deformation is for 20bar pressure



Von-mises stress over in the tank





Stress in X-direction **stress in Z-direction**

Conclusion

Finally we conclude that the tank design is under limit. The highest pressure is observed at the nodes given by you. And those are not activated since I sat in this chair. Finally we can go for manufacturing and in future need to work on buckling analysis.

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