CFD Analysis of Composite Cylinder for CNG Vehicle

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Abstract— Natural gas is an eco-friendly source of energy due to its wide availability and safety during operation. It is a viable solution for current environment threat of pollution; however the transportation problem due to low density restricted its wide usage. Burst pressure prediction helps to estimate the load carrying capacity of vessel and prediction of burst pressure in different working condition is cumbersome work. Finite element method and continuum damage mechanics study used to study burst pressure. FEM techniques various model used to predict stress and burst pressure in academic scenario.

Keywords: Composite Cylinder, CNG Vehicle

I. INTRODUCTION

The different advantages of CNG as compared to gasoline like it are lighter in weight as well as higher self-ignition temperature. CNG has 700OC ignition temperature. It has lower exhaust emission with lower cost as compared with gasoline product. The use of compressed natural gas (CNG) as a vehicle fuel has been growing worldwide due to the advantages of significant reduction of exhaust emission and lower fuel cost compared with gasoline. CNG cylinders are fabricated to bear high pressure so they are safer than petrol storage. The disadvantage regarding CNG is leakage of gas which causes fire and explosion of tank.

Obviously good strength design consideration prevents leakage and explosion of cylinders. The major accidents due to disconnection related to fuel pipe and human errors, some are related to wrong fuel filling practices and chassis failure of vehicles. Overall more than 1.5 crores vehicles in 2011 and it's extended to 38% in Asia only. With good quality control and implementation of good design within standards and regulation may improve the use of CNG vehicles and reduces the accidents up to certain extent.

In present Day mainly four types of CNG cylinders In use namely seamless metallic cylinder, lining cylinder with carbon fiber overwrap, next is overall carbon fiber or fiber glass cylinder and Type four is basically non-metallic cylinder with carbon fiber or fiberglass. Constructions of CNG cylinder are good in strength to weight ratio with corrosion resistance. Cylinders with composite material with metallic liners are to prevent gas leakage at high pressure.

II. LITERATURE REVIEW

Mayank Nirbhay et. al simplify the secure processes pressure with CNG composite cylinders. By using ANSYS, finite element tool diverse operation provision to study different failure of CNG vessels were proposed. Materials like glass epoxy as well as carbon epoxy were tested as per condition in composite cylinder design. The working stresses were found 1498 MPa for carbon fiber and 870 MPa for glass and carbon fiber combination. All tests are done in three pressure range i.e. 20 MPa, 30 MPa and 73 MPa.

Pranjali Sharma et. al studied different composite pressure vessels for automotive applications for their lightweigh properties for the reason that of their capability to stock up high pressure gaseous fuel. Study compromises design factors to reduce burst and leakage in Type 4 cylinders. Design also suggested the optimized manufacturing to enhance product performance. Results validation of design had done by comparison of experimental burst pressure. After validation, lightweight as well as economical vessel manufactured as per design consideration to analyzed burst pressure. Study focused on manufacturing of type 4 vessel as per design with experimental data as well as also focused on Manufacturing defects like slippage of fiber and winging brakeage can be eliminated by simulating bursting pressure. The planned methods also concluded the different volume of pressure vessels and composite layers thickness with their numbers prevents different failures. Estimated cost of cylinder is near about 50000/- INR found economic as compared with available cylinders in marketplaces with certification of ISO 11439 ranges 50MPa.

Eui Soo Kim et. al targets the threats of fossils fuel in comparison with CNG gases vehicles with environmental issue. There should be a reliability regarding storage of CNG tanks to avoid traveler losses and damages. By use of fractography, failure identification had done to overcome fracture of vessel and fire. The design of vessel was validate with the help of finite element method. ANSYS applied in design and analysis of composite cylinders with their mechanical properties and chemical properties with the help of fractography method. Stresses value up to 850 MPa satisfies the design result in the case of the bursting pressure. Vessel divided in three studied zone upper part consisting dome, ruptured part or middle part and last dome part related to lower part. Crack formation initiated from middle part and lower dome also affected in clamp bolt and vessel junction.

K. Rajendra Prasad et al. represent the design and finite element study on high pressure cylinder of different epoxy composites. Cylinders at high pressures are generally used in automobile as well as aerospace projects. Pressure cylinder developed different pressure constraint like hoop and longitudinal. Comparing different fiber reinforced material with high specific strength at different condition of pressure. Pressure cylinders like UD epoxy carbon shows less weight as compared with conventional material and shows less stresses and deformation. Internal pressure ranges under 14 MPa for different application like CNG Auto composite materials are the greatest alternative.

III. RESEARCH METHODOLOGY

Operating temperature	Operating pressure	Filled medium	Water test pressure	Design bursting pressure
-40°C to 60°C	20 MPa	Natural gas	30 MPa	73 MPa

Table 1: Operating Conditions of all-composite gas cylinder (Yue and Li (2012)

As per literature review, there are some key points emerges, there is some safety measures which are useful to prevent accidents and causalities due to breakage or leakage of compressed gas cylinders of vehicles, training to driers and co drivers can also prevent hazards effect of bursting during accidents. In design consideration there should be lighter material to overcome weight ratio and balance vehicle weight. There is Type 4 type composite cylinders which are useful and give higher strength. There are possibilities to find better materials to giver better strength with lower density and lower in weight also.

In continuation to this, present research work contains better material with their different properties as per comparison. This research work basically consists of three different materials i.e. Kevlar, Boron and T700 tested in combination with outer and inner layer. Present research work consist of three composite material, Kevlar, Boron and T700 known for their good strength and moderate mechanical properties, also impactful in density factor and low weight ratio. Test uses ANSYS model to simulate in three pressure condition of pressures known as operating pressure, water pressure and bursting pressure which are 20 MPa, 30 MPa and 73 MPa respectively. Cylinder dimension taken from paper and after meshing there is validation of past results. After this simulation with ANSYS software at different operating pressure condition have been done. Present research exhibited, two basic results first is deformation under pressure and other is stress development over the cylinder.

IV. Result and Discussion

Figure 3 clearly shows the maximum variation of deformation of cylinder under all three pressures. Figure depicts maximum deformation at T700 and Kevlar combination as inner and outer layer respectively among all 6 combinations of materials. However the lowest deformation is Kevlar and Boron among all combination which is essential for cylinder design. The values for lowest deformation is 0.69mm, 1.04mm and 2.52mm at 20 MPa, 30 MPa and 73 MPa respectively. The second lowest deformation is T700 and Boron combination as inner and outer layer.

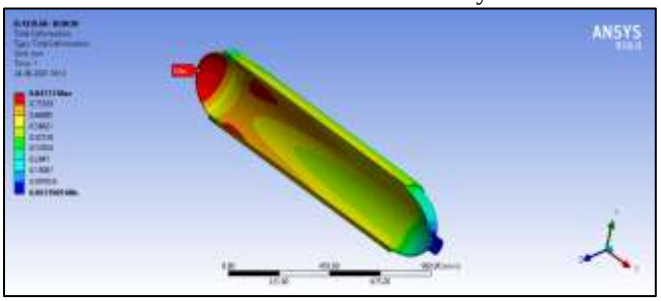

Fig. 1: Axial Deformation of composite gas cylinder under pressure 20 MPa Kevlar & Boron.

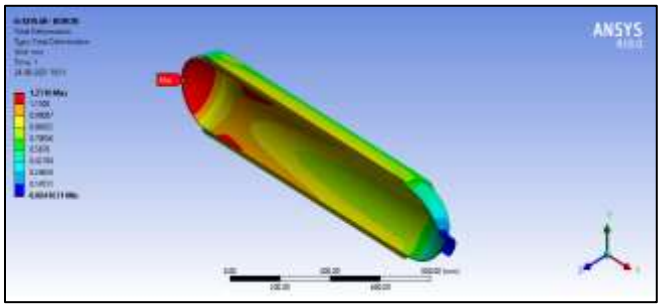

Fig. 2: Axial Deformation of composite gas cylinder under pressure 30 MPa

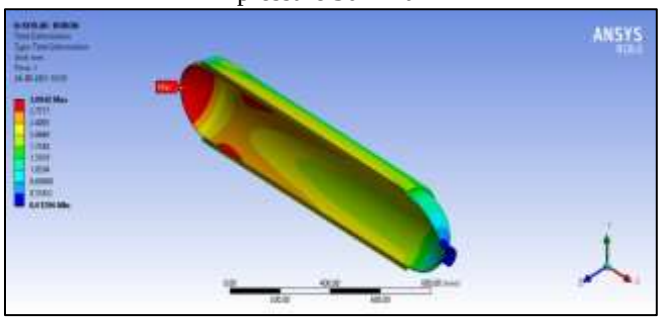

Fig. 3: Equivalent (von-mises) Stress of composite gas cylinder under pressure 73 MPa

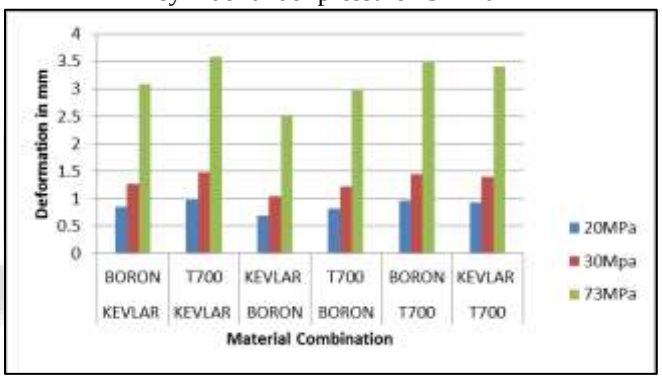

Fig. 4: Axial Deformation of all composite gas cylinder under all three pressure 20MPa, 30 MPa and 73 MPa

Figure 4 clearly shows the maximum variation of stresses of cylinder under all three pressures. Figure 49 depicts maximum stress at T700 and Boron combination as inner and outer layer respectively among all 6 combinations of materials. However the second maximum stresses is found at Kevlar and Boron among all combination.

With reference to above figure, present study clearly indicates the two best combination which are Kevlar- Boron (Kevlar as inner layer and Boron as Outer layer) as well as T700- Boron (T700 as inner layer and Boron as outer layer). In comparison with these two combinations present study recommended, minimum deformation and maximum stress is Kevlar and Boron combination which is best possible combination concluded.

1) This study comprises with three composites materials and its combination with each other. This study mainly conducted in combination of Boron, Kevlar and T700 composite materials and their combination with each other. Hence 6 main combinations were found which enlisted as Boron – Kevlar, T700- Kevlar, Kevlar-Boron, T700- Boron, Boron- T700 and Kevlar-T700. These six combination analysis with three operating pressure 20 MPa, 30MPa and 73 MPa to study maximum

deformation and equivalent Stress study under finite element method.

2) Maximum deformation is Kevlar and Boron among all combination which is essential for cylinder design. The values for lowest deformation is 0.69mm, 1.04mm and 2.52mm at 20 MPa, 30 MPa and 73 MPa respectively.
3) In comparison with these two combinations present study recommended, minimum deformation and maximum stress is Kevlar and Boron combination which is best possible combination concluded.

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