Effect of the number of layers of fiber in COPV PVC-Cotton on burst strength test

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Abstract. Composite overwrapped pressure vessel (COPV) is a pressure vessel wrapped or coated by composite fibers. COPV is commonly used to reduce the weight of pressure vessel. Usually COPV combine the metal liner and wrapped by the glass or the carbon fiber. How the influence of layers number to burst strength test is studied. The PVC tube is wrapped by the natural fiber (cotton) is used, and the burst test is applied. The specimens consist of four tube, a tube without wrap, a tube with one layer wrap, a tube with two layers wrap and a tube with three layers wrap. The experiment indicate that the layer effective to augment the strength of burst test until 50%, but the addition of the number of layers, did not really affect the increase in COPV burst strength test.

1. Introduction
The CNG pressure vessels which are made entirely of metal are relatively cheap, but due to the high pressure the weight of the tubes will be very heavy. This risk can be reduced by selecting composite overwrapped pressure vessels (COPV).

Composite overwrapped pressure vessel (COPV) is a pressure vessel that is wrapped or coated by a composite fiber. COPV is commonly used as a place or container of fluid that has a high pressure, such as oxygen, compressed natural gas, helium gas, and so forth. COPV consists of two layers, where the first layer serves to prevent leakage, while the second layer serves to withstand the pressure received by pressure vessels. The first layer is usually made of metal, while the second layer is made of composite.[1]

The first layer is usually made of metal but in this study will use PVC which serves to prevent leakage, while the second layer is made of a composite that serves to withstand the pressure received by the pressure vessel. COPV is designed with the hope of reducing the weight of pressure vessels without reducing resistance to high pressure.

The thickness of the composite fiber layer at COPV can determine the pressure of the pressure vessel. Pressure vessels for CNG need to be designed in such a way as to be able to withstand the enormous internal pressure of CNG. Operating pressure for CNG pressure vessels ranges from 100-200 bar. For this reason, it is necessary to test the thickness of the composite fiber in the COPV tube due to high pressure.
The thickness of the composite fiber layer at COPV can determine the pressure of the pressure vessel. Based on wall dimensions, pressure vessels can be divided into two, namely the thick pressure vessel has a wall thickness (shell) more than 1/20 shell diameter and thin wall pressure vessels have thickness the wall (shell) is less than 1/20 the diameter of the shell.[2]

Difference between thin wall pressure vessel and wall thickness is in the stress distribution that occurs on the wall of the pressure vessel, on the pressure vessel thin walls, stress distribution can be ignored because of the difference in outside diameter and diameter inside is so thin that the stress distribution is occurs very small, whereas in pressure vessels thick wall stress distribution must be taken into account.

When the thin cylinder is given internal pressure, there are three principal stresses which are perpendicular to each other ie, circular stress (hoop), longitudinal stress, and radial stress that reacts at cylindrical wall.[3-5]

2. Manufacturing and Preparation of Test Specimens
The specimen is made from PVC pipe and wrapped by the cotton fiber, for this study, four specimen is used. The effect of reinforcing fibers on COPV with PVC liners is obtained by testing the specimens in the form of PVC 4 inch in diameter, 3 mm thick, and 400 mm long which is then carried out by Hoop Winding. The Each test specimen consisted of zero, one, two, and three wrapped layer. The specimen thickness are presented in Table 1.

| Specimen no. | Composite Layers number | Thickness (mm) |
|--------------|-------------------------|----------------|
| 1            | n/a                     | 3              |
| 2            | 1                       | 4.1            |
| 3            | 2                       | 5.3            |
| 4            | 3                       | 6              |

3. Experimental Procedure
The objective was to characterize the burst test strength of COPV PVC-cotton fibers, and to know the possibility of this COPV used for gas tank. Testing on COPV (PVC-cotton Fiber) to burst (Burst Test) is done by the Hydrotest method. This test is carried out to get at what pressure the COPV is exploding. The test set-up is presented in figure 2. The pressure is generated from a manual piston pump, which is then channeled into the tube.
4. Discussion of Results
The test results obtained as shown in table 2, while the specimen images of the test results can be seen in Figure 3.

| Specimen Number | Number of layers | Pressure (bar) | Remark          |
|-----------------|------------------|---------------|-----------------|
| 1               | N/A              | 20            | explode         |
| 2               | 1 Lapisan Komposit | 25           | Explode, fiber fail |
| 3               | 2 Lapisan Komposit | 30           | Explode, fiber fail |
| 4               | 3 Lapisan Komposit | 30           | Explode, fiber no fail |

Figure 2. Test Set-up

Figure 3. Types of tubes failures; a, b, c, and d, respectively, show no layers, one layer, two layers, and three layers of composite fibers.
From the data obtained, it appears that the pressure that can be held shows an increase with increasing layers. But the increase is not linear with the stress experienced by the fiber when the tube breaks. Assuming that the breaking strength of the fiber is fixed, the stress value, both hoop and longitudinal, should increase linearly.

If observed from the type of tube and fiber failure when the tube breaks (see figure 3), for tubes without fiber or fiber-wrapped, have the same fracture shape, while fibers do not have the same
fracture characteristics, even for tubes wrapped by three layers of fiber shows that the fiber does not break.

Although the fiber does not break, but the fiber has a fairly large extension. this is what causes the stress experienced by the fiber to decrease when the tube experiences a maximum load.

5. Conclusions
From the analysis of the results, several conclusions were drawn. Namely, an increase in the number of layers of fiber used, can increase the breaking strength of COPV up to 50%. It became clear that the fiber elasticity doesn’t accommodate to strengthen the tube, this is also caused by the tension of the fiber when the filament winding process is not optimal.

Although the strength of the fiber is high, but the percentage of elongation is higher than the percentage of the linear strain, it is not recommended to be used as a COPV reinforcing fiber.

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