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EXTENDED ABSTRACT

Investigation on the Buckling Behavior of GFRP Thin-walled Cylindrical Shells under External Pressure

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Cylindrical tanks, Geometric parameter, Buckling capacity, GFRP materials, External pressure.

1. Introduction

Structural applications of composite materials are used in various structures of the oil and gas industry, water supply and sewage systems and a wide range of industries, such as marine, aerospace, and military industries. Experimental and numerical studies show that structural buckling failure is the major dangerous action for thin-walled cylindrical shells. Uniform lateral loading in tanks occurs when tanks are in a state of liquid discharge. Moreover, if special contrivances such as the drainage valves do not work or properly, then buckling phenomenon and will cause an overall failure in the tank. There is extensive research on the buckling and post-buckling of thin-walled steel tanks under external pressure, but research on composite cylindrical shells is very low. The only studies in the context of buckling of external pressure are done, by Hur et al. (2008) and Moreno et al. (2008), with the difference that in both studies, the type of material and loading is different from the present study. In this paper, the effect of the L/R geometrical parameters on the buckling behavior of GFRP cylindrical tanks will be studied.

2. Methodology

2.1. FE modeling

The Abaqus software (2012) has been used to provide finite element modeling. The specimens are models in 200 mm in radius and 200, 300 and 600 mm in height and 1, 2 mm thick. In modeling the multilayer composite cylindrical shell in the Abaqus software for the mesh used of four-sided and four-node elements (S4R), which is a two-curved element and has the ability to analyze large strains. The loading and boundary conditions of the model are determined in the loading environment. To apply external pressure, the inner surface of the cylinder is first selected. The supporting conditions of the samples are arranged in detail. The bottom part is tangential in the three radial, tangential, and axial directions. At the top, the specimens have only radial and tangential Constraint, and the axial movement is free. Since linear buckling analysis does not allow prediction of post-buckling behavior, a nonlinear geometric analysis using Riks algorithm was used to find out the behavior of buckling.

2.2. Laboratory investigation

2.2.1. Investigation of buckling behavior of tanks

In order to determine the buckling capacity of the GFRP tanks, three specimens of the same diameter and thickness and only length variable were prepared and tested under external pressure. By decreasing the pressure inside the tank, the buckling begins gradually in the shell body, with continued loading and by

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increasing the external pressure of the small cracks along with the mild sound created in the tank body and increasing the number of environmental waves after reaching the collapse stage. Displacement- pressure diagrams are given for the samples.

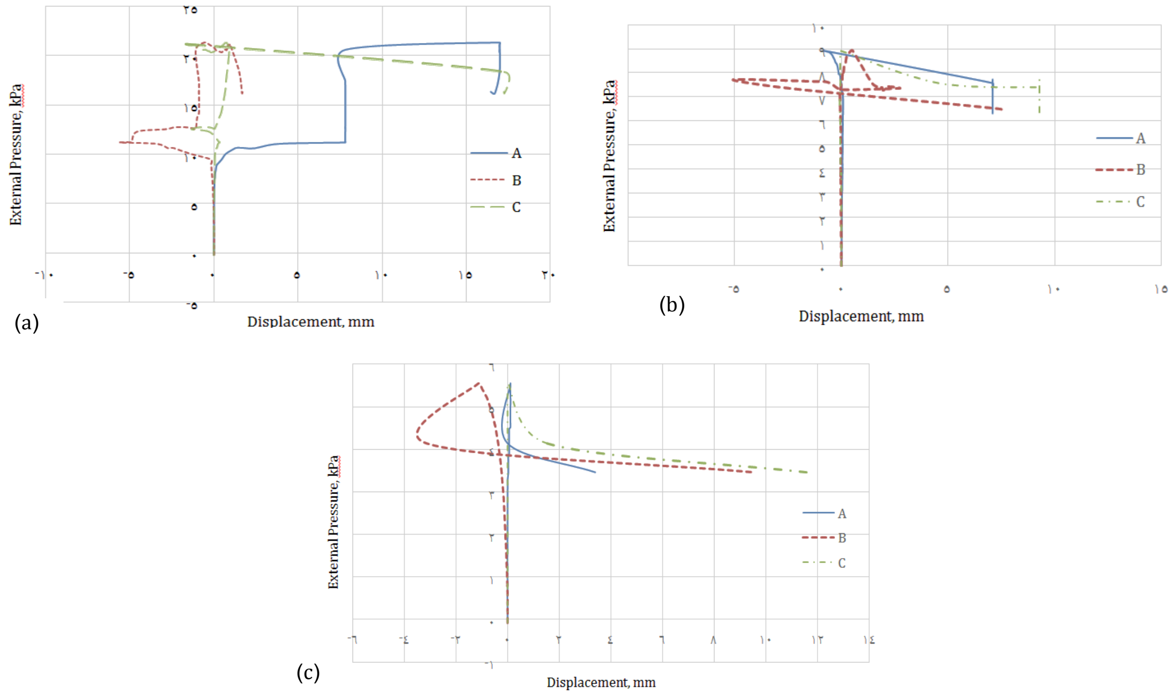

Fig. 1. Pressure- displacement diagram: a) SGF1- P Specimen, b) SGF2- P Specimen, c) SGF3- P Specimen

2.2.2. Investigation of buckling and elastic behavior of tanks in repeated test

To investigate the buckling capacity of thin-wall composite shells under uniform external pressure due to repeated buckling at this stage, two previous laboratory samples were subjected to external pressure loading after the test for the buckling capacity and elastic properties of GFRP tanks were repeated at uploading and downloading to be examined. Displacement- pressure diagrams are given for the specimen.

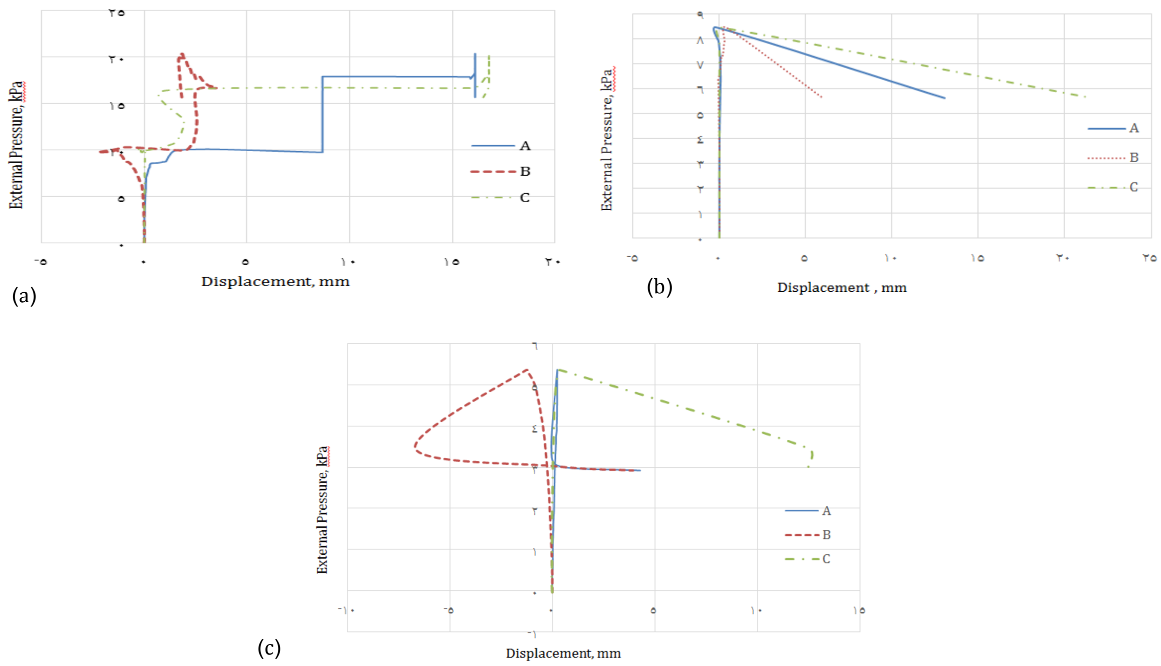

Fig. 2. Pressure- displacement diagram: a) SGF1-R Specimen, b) SGF2- R Specimen, c) SGF3- R Specimen

3. Results and discussion

3.1. Results of the numerical and Laboratory methods of the Specimens in the initial test:

According to Fig. 1, the buckling capacity in the laboratory compared with the numerical method. In this comparison, the laboratory buckling capacity ratio numerical showed a decrease in buckling capacity in SGP1 sample by 14.69%, SGF1 sample by 14% and 14.69%, SGF2sample and in SGF3 sample by 21, 4%. This is due to some physical and geometric disadvantages, but they are well adapted. And by increasing the L/R ratio from 1 to 1.5 the tank capacity reaches to 84, 75% (15.25% decreases in buckling capacity) and from1 to 3 the tank capacity reaches to 47, 36% (52, 64% decreases in buckling capacity).

3.2. Results of the sample Laboratory method in the initial test and repeated test:

In this section, the results of the buckling capacity of the specimens were investigated by SGF1, 2, 3-P specimens after being subjected to external pressure and their buckling behavior evaluated again under uniform external pressure loading. The tests were evaluated and compared with the results presented in Figure 2. According to Fig. 1 and 2, SGF1-P sample, buckling occurred at 9,46 kPa while in the same test repeat it decreased to 8,7 kPa, that's mean 8,03% decreased in capacity, and in SGF2-P sample buckling at 8 kPa while the test sample repeated occurred at 7,22 kPa buckling, with a 9,75% decrease in buckling capacity and in SGF3-P sample buckling at 4,48 kPa while the test sample repeated buckling occurred at 3,8 kPa, with a 15,18% decrease in buckling capacity, that means the specimens in the repeat test were unable to repeat the initial buckling capacity, but it was interesting to note that they also had a good buckling capacity and returned to the original after downloading. That shows the good elastic properties of composite tanks.

3.3. Results of numerical and Laboratory buckling modes:

According to the studies, there is a difference in the number of investing and numerical methods and this difference in samples with L/R equals 1, three modes and in L/R equals1, 5, two modes and in L/R equals 3, one mode which means that As the length of the tank increased, the difference in the number of modes was reduced by numerical and Laboratory methods.

4. Conclusions

The present study was to investigate the buckling capacity of the numerical and experimental data and to investigate the buckling capacity in repeated experiments on GFRP cylindrical specimens with different radii and lengths, which can be summarized as follows.

Shell behavior against increasing pressure showed a steady-state, and the trend of displacement increase versus pressure increase indicates a behavior with a constant gradient. Laboratory Results although some of the geometrical and physical imperfections are lower than the numerical results, but they are in good agreement. 3- Examination of the effect of increasing the height of the GFRP tank shows that with increasing tank height, the buckling capacity decreases. Examination of the results of the repeated test of the samples showed that the samples in the repeat test could not replicate the initial capacity but had good capacity. The results showed that the GFRP tanks had good elastic properties so that they could return to their original state after unloading, although they did not show in the metals. The results of the research showed that the number of buckling modes decreased significantly with the increase in tank length. The results showed that the buckling modes were the same in the initial test and the repeated test of the tanks. The results show that due to the good elastic properties of GFRPs, they are a good substitute for metallic tanks.

5. References

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