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The Experimental Model of the Pipe Made of a Composite Material under the Effect of Internal Pressure

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Abstract-This work is based on the classical laminated-plate theory for the elastic solution of the stress and strain in the hollow cylinder fiber-reinforced sandwich pipe under effect of internal pressure. The experimental pipe model was developed for the multilayer fiber-reinforced composite laminates. Considering the complicated material properties of the skin layers reinforced by alternate-ply composites, the stress analysis is based on treating typical multilayer cylindrical and orthotropic pipes. The constitutive model is tested in against the experimental data and, as a result, the satisfactory results are obtained. In addition, parametric studies of composite laminates with different laminate layups and under various internal pressure load ratios are presented.

Key words: *composite materials, internal pressure, hollow cylinder, strain gauge, and flange.*

I. Introduction

The development of sandwich-type pipes for many industrial products utilizing composites has already gained a considerable attention. Among their applications, a common feature of such products is that they have to undergo safely a certain working pressure. The filament-wound pipes made of fiber-reinforced plastics have many potential advantages over pipes made from conventional materials. A number of researchers have investigated failure mechanisms of lament-wound pipes. For thin-walled cylindrical-pressure vessels with a ratio of applied hoop-to-axial stress of two to one, an optimum winding angle of 55° was noted, and many experimental failure analyses were conducted for filament-wound pipe with a 55°-winding angle [1-4]. Most of the previous studies on cylindrical fiber-reinforced composite structures have focused on thin-walled cylindrical shells. However, only limited studies have been published concerning thick-walled cylindrical pipe behaviours [5-9].

II. Experimental work

There were conducted the tests of a hollow cylinder made of composite materials. Layout of strain gauges (TR) was determined at the planning stage of the experiment. Figures 1, 2, show how to install strain gauges and dimensions of flange and figure 3 shows the devices and equipment used in the tests.

Marking the location of strain gages in this case facilitated the presence of eight mounting holes on the flange of the pilot cylinder. Therefore, under the strain gauge location selected on diametrically opposite sides of the cylinder with the fewest defects (sags, irregularities).

The gauge distance between the centre holes on the flange was defined. Then, the resulting point with polygon was transferred to the lateral surface of the cylinder and the centre line was applied to accommodate the eight strain gages.

The next operation is preparation of a pole sticking gages with the rough "skin" on a flat mandrel, all the bumps and nodules were removed, and then gluing in the place of strain gauges the fine "sandpaper" surface was finally tipped. After that, the surface was degreased with acetone.

In parallel, you should check all gages with a tester against the resistance of 200 Ohm. If the test result is positive, we obtain findings of TR tin.

The next step is to degrease gages by dipping them in acetone (one). After drying the acetone the layer of adhesive and strain gauge are installed and pressed for 0.5-1 minutes using a dense polyethylene film. Then, foil and stuck are removed to release the findings, gently lifting them to a free state. The next operation is the organization of the shared bus (chain) of all gages.

The next stage is the individual styling of each wire on all gages at a time. The wires should be laid without the "tightness" in order to create internal stresses in the cylinder, each pin and wire gage have to be able to move freely without any breaks.

As the resistance meter SIIT-3 mode 1/4 of the bridge was used.

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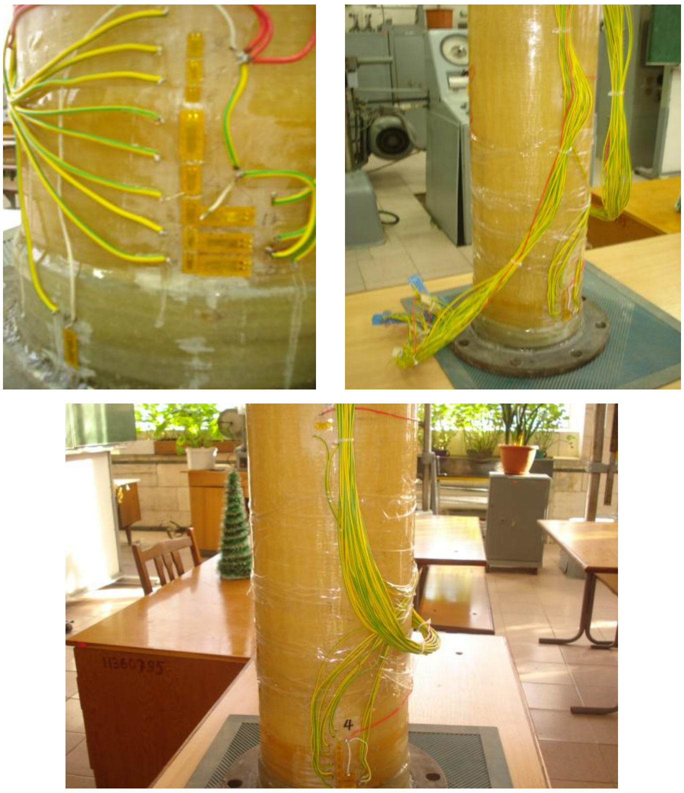

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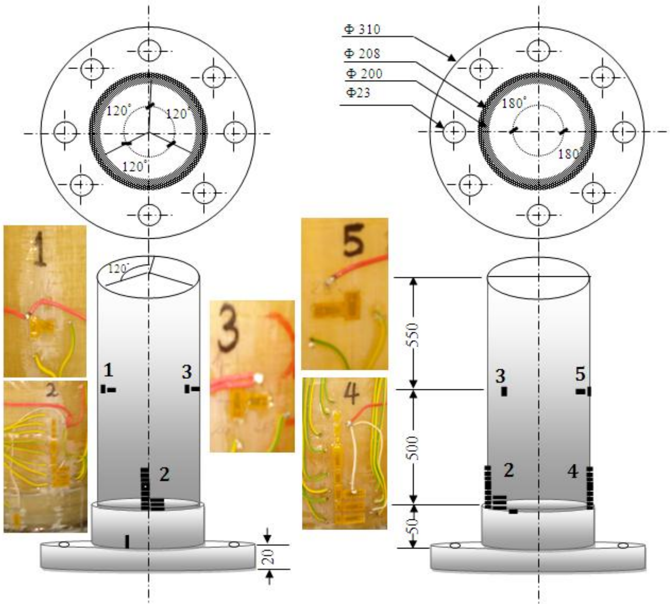

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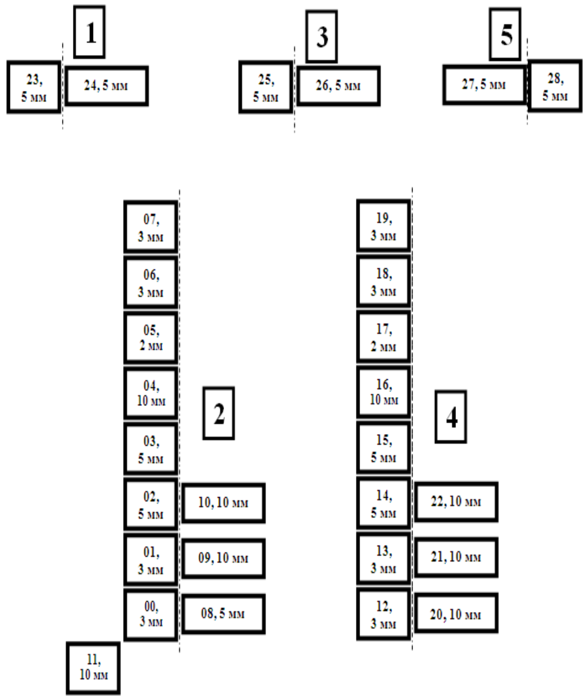

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Figure 1 Show points of clay strain gauges

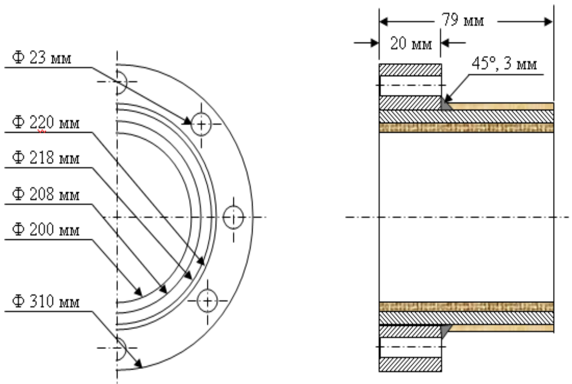

Figure 2 Show dimensions of flange

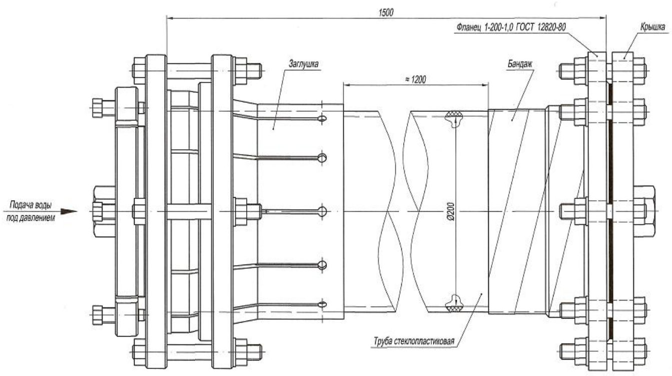

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Figure 3 Shows the devices and equipment used in the tests

The test set: There is a water pumping station with the ability to create any given pressure in the range (0 - 250 atm.) Test: medium water is fed through a special nozzle located in one of the plugs into the test object. To protect from water splashes during a possible fracture, the test object is placed in a special tilting box during the test. The slope of the box provides a quick drain in emergency situations and at the end of the test.

Plug 1 consists of 3-cylinder with grooves into which there are placed two toroidal rubber gaskets piston mounted on the basis of diameter 300 mm, 20 mm. The base has four through-holes through which the component parts piston screws compress the toroidal sealing gaskets to complete the test object. Along the perimeter of the base there are 16 holes with a diameter of 16 mm with the bolts of the cutting cone a lot of petals imposed from the outside of the test cylinder.

If the pressing force is transmitted from the base cap bolts to a special ring, which compresses the split cone a lot of petals, compress the test cylinder from the outside to create the necessary buoyancy force counteracting the action of the test medium (water).Test object represents a composite cylinder with a diameter of 200 mm, wall thickness 4 mm, length - 1,200 mm. From one end of a cylinder embedded in a steel flange designed to mate with the rest of the system (operating, testing, etc.). The depth of the junction of the cylinder with a flange of 50 mm. The ttype of termination is bonding: in the tests referred to a special flange the flat cap with flat and toroidal rubber gaskets was plugged. The deformation was recorded on a digital measuring system SIIT-3. A. Originally loaded with up to 35 atm. (0,5,10 ... 35 at.). The next stage discreteness of the previous steps, registrar of the same strain. When a load of 40 atm frustrated adhesive joint test of the cylinder flange. See Protocol N22, photos. A. Decision: To cut off the flange and continue testing until the destruction of the cylinder.

Figure 4 Shows the area of the flange forms the brink of collapse

Instead of cut flange installed another plug one described above, removing the pre-wire strain gages, and to them, register the strain in the flange. The loading is still carried out in steps of 5 ATN. See Protocol N23. Starting with the pressure of 40 atm. at each stage of loading could be heard crackling (destroyed the outer layer of the matrix). At 65 atm pressure, ruptured gasket on one of the plugs. After replacing the gasket, the passage of the load (0-65) atm. crack is almost tapped with further loading (after 65 atm.) resumed cracking intensity. Under load (135 atm.) Cut one of the plugs (first) and decided to stop testing.

III. ANALYSIS AND RESULTS

The results were obtained after conducting several experiments under various pressures using twenty-eight devices distributed differently on the surface of the cylinder. The rresults were analysed in Excel program to get the modulus of elasticity and Poisson ratio. The obtained results were very satisfactory and table (1) and fig. (4) present the results of various tests.

TABLE 1 The results of various tests for the model in the form of a cylinder of composite material

Number of Experiments	Load (MPa)	Maximum Load (MPa)	number of strain gauge	Modulus of elasticity, E (MPa)	The average modulus of elasticity, E (MPa)	Poisson's ratio, υ	The average Poisson's ratio, υ
1	5	30	6	3.984* 10^4	3..632*10^4	0.383	0.435
2	5	30	6	4.034* 10^4		0.433	
3	5	30	6	3.539* 10^4		0.433	
4	5	65	6	3.333* 10^4		0.444	
5	10	130	6	3.269* 10^4		0.483	

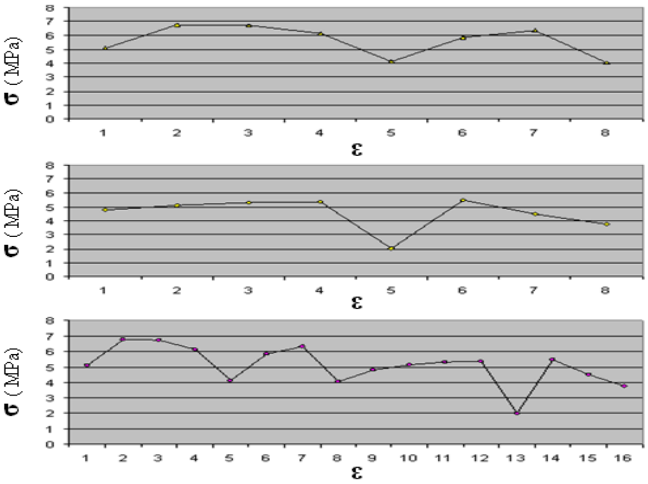

Figure 4 The results of various tests for the model in the form of a cylinder of composite material at the flange

IV. CONCLUSION

This research presents a method for the analysis of the stresses and strains of pipes made of a multilayer composite material subjected to internal pressure. This procedure is based on the classical laminated-plate theory. The pipe is considered in 3D analysis and in an orthotropic-material model. The developed experimental method provides a basis for predicting the elastic behaviour of the multilayer composite material pipes.

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