



**XII INTERNATIONAL  
CONGRESS  
"MACHINES, TECHNOLOGIES,  
MATERIALS"  
16-19.09.2015, VARNA,  
BULGARIA**

**HOOP TENSILE PROPERTIES OF FILAMENT WOUND PIPES**

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**1. Introduction**

Filament winding technique can be accepted as one of the most common production techniques, for the synthesis of polymer matrix composites (PMC). Filament winding is a process where the reinforcing agent in the form of continuous fibers (glass, carbon, aramid, etc.) is accurately positioned in the impregnation agent in the form of liquid resin (polyester, epoxy, etc.) to form a cylindrical shape (Figure 1). A number of fiber rovings are pulled from a series of creels and tensioners that control the tension of the fibers into a liquid resin bath that contains the resin itself, the hardeners and the accelerators. At the end of the resin tank, the rovings are pulled through a wiping device where the excess resin is removed from the rovings. Once the rovings are thoroughly impregnated and wiped, they are collected together in a flat band, pass through the carriage and located on the mandrel. The traversing speed of carriage and the winding speed of the mandrel are controlled to generate the desired winding angle patterns. After the appropriate number of layers has been applied, curing is carried out in an oven or at room temperature, after which the mandrel is removed.

The filament winding method in general, has several advantages over other methods.

- It is highly repetitive and precise in fiber placement.
- It can use continuous fibers to cover the whole component area, which simplifies the fabrication process of many components and increases reliability and lowers the cost by reducing the number of joints.
- It is less labor intensive, which reduces the costs significantly.
- Large and thick walled structures can be built.

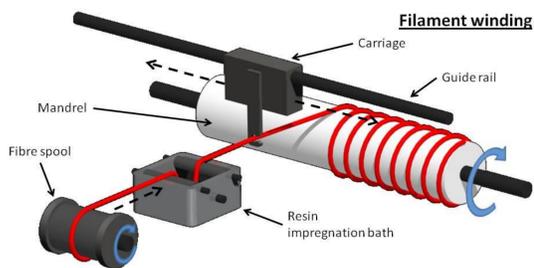


Figure 1. Schematic presentation of the filament winding technology

Three types of testing geometry are commonly used in testing of filament-wound composite structures, namely: flat specimens (coupon specimens), ring specimens, and tubular specimens. Axial (tension/compression), shear, and bending response of each testing geometry can be determined by applying a suitable loading to the specimen. For evaluation of the tensile properties of filament wound composite structures split-disk test is usually used.

Proposed ring shape of samples may be applied in axial tension test, internal pressure test, etc., as well as their combinations. Hoop tensile strength of specimens can be determined with help of split-disk test. Split-disk tests are very efficient in determine the performance of tubular structures which are usually used under internal pressure developing high hoop.

This research will present the hoop tensile properties of different models of specimens based on the different winding angle, manufactured with conventional filament winding equipment

**2. Preconditions and means for resolving the problem**

Samples with different winding designs were wound on iron mandrel with help of laboratory filament winding machine MAW FB 6/1 with six axes, roller type resin bath manufactured from Mikrosam A.D. The filament winding machine is given in Figure 2.



Figure 2. Filament winding machine MAW FB 6/1

The resin system employed in the fabrication of the pipes is Araldite LY564/Aradur 917/Accelerator 960-1 from Huntsman. The reinforcements employed in the fabrication of the pipes are 10 bobbins of E- glass fiber roving 185P with 1200 tex from Owens Corning (Table 1).

Table 1: Designation of models of samples

Number of samples	Characteristics (conditions of the experiment)		
	X <sub>1</sub> (m/min) velocity of the filament winding	X <sub>2</sub> (N) fiber tension	X <sub>3</sub> (°) winding angle
1	21	110	<b>10</b>
2	21	110	<b>45</b>
3	21	110	<b>90</b>

Winding angle is the angle between fiber and the line on surface of the mandrel, which is parallel to mandrel axis. Coupled helical winding of layers ( $\pm \theta$ ) are usually preferred, whereas hoop winding - winding angle, very close to 90° and winding with very low winding angle can also be used. By varying the winding angle with respect to the mandrel axis, directional strength can be obtained by considering the loads, which will operate on the finished product.



Low winding angle ( $\theta = 10^\circ$ )



Helical winding ( $\theta = 45^\circ$ )



Hoop winding ( $\theta = 90^\circ$ )

Figure 3. Winding of impregnated glass fibers

Calculated mass ratio between fiber and resin of the produced composite pipes was 75:25 wt. %. After winding samples were cured with industrial heater at 80°C and at 140°C, for four hours. After the curing operation, the removal of the mandrel from the specimens was performed. In this experimental study the investigation of the effect of winding angles on hoop tensile strength of glass fiber reinforced filament wound ring specimens was performed.

**3. Results and discussion**

For tensile tests three split-disk test specimens from each model of filament wound pipes was cut according to ASTM D2290. Tensile tests of split-disk samples were carried out at room temperature using universal testing machine Schenck with max load of 250 kN and loading speed of 5 mm/min. Width and thickness of each split-disk samples was measured with help of micrometer with reading to at least 0.0254mm. In this way prepared specimens were elongated till rupture with help of test fixture, made according to standard (Fig. 4).



Figure 4. Split-disk test specimen and test fixture with specimen for hoop tensile testing

Table 2: Hoop tensile strength results of split-disk tests

	Sample Designation	Weight (g)	Width (mm)	Thickness (mm)	F <sub>max</sub> (N)	Tensile strength (MPa)	Winding angle (°)
<b>1</b>	1-1	42,2	13,97	3,18	1600	18,00	10
	1-2	43,0	13,85	3,14	1250	14,34	
	1-3	43,7	14,00	3,14	1759	20,00	
<b>2</b>	2-1	53,6	14,01	3,18	25000	280,57	45
	2-2	53,8	13,9	3,16	24225	275,76	
	2-3	53,8	14,01	3,16	24400	275,57	
<b>3</b>	3-1	52,8	14,06	3,64	94500	923,24	90
	3-2	52,8	14,12	3,64	90250	877,97	
	3-3	53,8	14,12	3,65	93000	902,25	

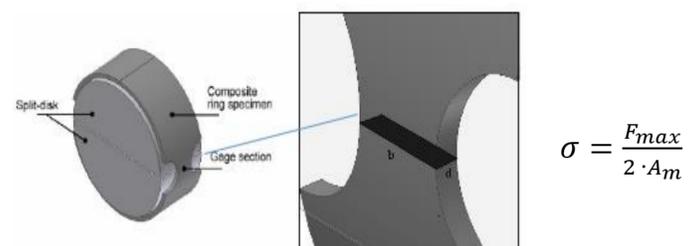


Figure 5. Cross-sectional area on which hoop tensile stress is applied

**4. Conclusion**

From results of the mechanical testing can be concluded, that the best results in tensile strength and break force were obtained from composite pipes winding with angle 90°. Split-disk specimen 3 with tensile strength with average value of 901,15MPa had shown the best results and it was wound with angle 90°. The specimen designated with 1 wound with angle 10° had shown much lower value up to 10 times lower than tensile strength from sample 3. Change of winding angle will cause variation in the final mechanical results, whereas that bigger winding angle lead to higher hoop tensile properties of filament-wound tubular samples.