EXPERIMENTAL METHOD TO INCREASE THE LOADING CAPABILITY OF GLASS-FIBRE REINFORCED COMPOSITE TUBES

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ABSTRACT

The paper presents an original method to increase the loading capability of glass-fibre/polyester composite tubes by applying internal stresses in thin-walled cylinders with only a few wound layers. A very simple device has been developed to attain this end. Various tube specimens with following features were carried out at SC COMPOZITE SRL Brasov: - inner diameter: 80 mm; - fibre content: 15% and 35%; - total wall thickness: 2…5 mm; - number of layers: 8; - length: 100 mm and different fabric disposal of reinforced material. The method consists in the accomplishment of following steps: Stage one. A tube specimen is manufactured in the fabric winding process. Stage two. The device is positioned and fixed vertically. Stage three. The specimen is heated above the glass transition temperature. Stage four. While keeping the temperature, a silicone rubber is pressed at the inner of the tube specimen. Stage five. While keeping the inner pressure, the tube specimen is cooled at environmental temperature. Stage six. After cooling, the tube is discharged from the inner pre-tension pressure and in wall structure will remain internal stresses. In the High Pressure Laboratory of Mechanical Engineering and Research Institute SC ICTCM SA Bucharest, the pre-tensioned tube specimens were subjected to internal hydraulic pressure until weeping occur. Micro cracking and delamination were the most observed damage mechanisms and combination of the two constituted most failures. Using this original method of pre-tension, the loading capability of glass-fibre/polyester composite tubes is increased up to 43%.

INTRODUCTION

Purpose of pre-tensioning glass-fibre reinforced composite tubes is to introduce internal stresses in tube wall structure, that can work against the operational stresses. These internal stresses increase the tube loading capability and its cracking limits. To attain this aim, a very simple device has been designed and developed. A silicone rubber that can be pressed at the inner of the composite tube represents the central part of the device. This rubber has the property to transmit the pressure in any direction.

THE PRE-TENSION METHOD

The method consists in the accomplishment of the following successive steps: Stage one. The tube specimen is manufactured in the fabric winding process. After solidification, the specimen is pulled-out of the mandrel. Stage two. The device is positioned and fixed vertically. Stage three. At this step, the tube specimen is heated with 5°…10°C above the glass transition temperature T_G. In this field of temperature, the resin elasticity modules decrease rapidly and the resin matrix became highly elastic. Stage four. The heated tube specimen is introduced into the device and then a silicone rubber is pressed at the inner of the tube. Since during the heating of the specimen, the matrix elasticity modules decrease, the inner pre-tension pressure will be taken over by the fibre network. Stage five. While keeping the inner pre-tension pressure, the tube specimen is cooled at the environmental temperature. Stage six. After cooling, the tube specimen is discharged from the inner pressure. Now, the fibre network will relax and in wall structure will remain a status of internal stresses.

After these six stages, the tube specimen is removed from the pre-tension device and it is stored 24 hours in a controlled atmosphere room (T=20°C and 50% air relatively humidity). This is necessary to reduce the internal stress relaxation due to possible strong temperature and humidity changes. 24 hours after this operation, in the High Pressure Laboratory of Mechanical Engineering and Research Institute SC ICTCM SA Bucharest, the pre-tensioned tube specimens were subjected to internal hydraulic pressure until weeping occur. This weeping pressure produces irreversible damages in the tube wall structure, such as micro-cracks and delamination.

TESTING OF THE TUBE SPECIMENS

The tube material used during the tests is a thermorigid compound based on glass-fibre reinforced polyester resin. At SC COMPOZITE SRL Brasov, The tube wall structure was manufactured very accurate in the fabric winding process. The fabric strip (dimensions: 2000 x 250 mm) used in winding process was cut in length, width and at 45° from the production direction. Geometrical elements and the specimens wall structure used in tests are shown in table 1 and the pre-tension characteristics are shown in table 2.

Table 1. Geometrical elements of the tube specimens

Geometrical elements	Units of measure	Value
Inner nominal diameter *DN*	[mm]	$80_0^{+0.4}$
Mandrel length L_D	[mm]	150
Specimens length *L*	[mm]	100
Total wall thickness *t*	[mm]	2 – 5
Number of layers *n*	[-]	8
Relative wall thickness $t_1=\ldots=t_8$	[mm]	0.25 – 0.62
Winding angle a	[°]	0; +45
Fibre content f	[%]	15; 35
Specimens weight average *G*	[g]	70 – 190

Table 2. The pre-tension characteristics of the tube specimen

Pre-tension characteristics	Units of measure	Value
Pre-tension pressure p_p	[MPa]	1.37
Specimens heating average temperature *T*	[°C]	105
Cooling environment	[-]	air
Pre-tension average time t_{AIR}	[min]	15
Cooling environment temperature T_{AIR}	[°C]	2

Six specimen types were manufactured and from every type, two pieces were carried out. The specimen types used in the tests are shown in table 3.

Table 3. Specimen types used during the tests

Specimen	Fabric type	Resin type	Fabric disposal
Type 1	STRATIMAT	POLYESTER	-
Type 2	FER3	POLYESTER	in length
Type 3	FER3	POLYESTER	at 45°
Type 4	FER5	POLYESTER	in width
Type 5	FER5	POLYESTER	in length
Type 6	FER5	POLYESTER	at 45°

EXPERIMENTAL RESULTS

The experimental results of the tests (weeping pressure and the increase of tubes loading capability) are shown in figure 1.

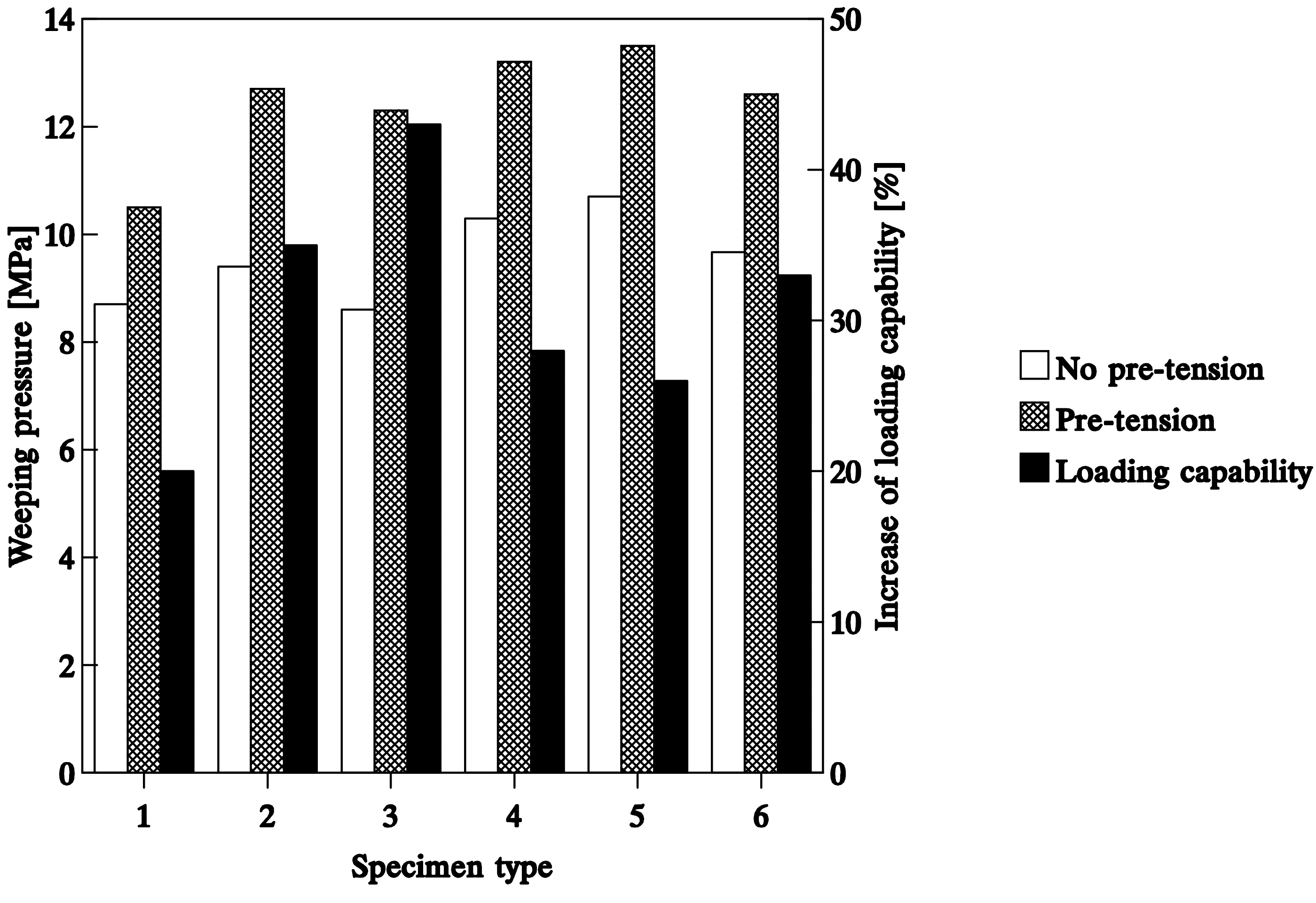

Figure 1. Weeping pressure and the increase of specimens loading capability

CONCLUSIONS

The following conclusions can be drawn:

Using this original method of pre-tension, the increase of tube specimens loading capability is situated between 20% (specimen type 1) and 43% (specimen type 3). This method emphasized a low structure endowment with internal stresses, which suppose a reduced pre-tension operation due to a prudent choice of the pre-tension pressure. This pressure can cause cracks and other damages in the tube wall structure.

The choice of the pre-tension pressure represents a ticklish problem and depends decisively on the composite material type, the pre-tension method used and on the pre-tension process parameters (especially the pre-tension temperature).

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