DOI: 10.2478/v10077-011-0004-x

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ON DEGRADATION OF GLASS/POLYESTER LAMINATE IMMERSED IN WATER

ABSTRACT

Mechanical behaviour was compared for glass/ polyester laminates manufactured in the boatbuilding plant using three methods: hand lay-up, vacuum bagging, infusion. Specimens were tested in dry condition and following accelerated water immersion test (70^0C- corresponding to the exposure of 30 years at 19^0C). In three point bending test 40-50% reduction in laminate strength was observed due to water immersion. The highest degradation was in samples manufactured using hand lay-up method, the differences in strength between both vacuum methods were insignificant. Interlaminar shear strength was reduced by 25% for infusion method which is recommended as the most efficient. Matrix plasticization and debondings as well as surface microcracks were responsible for reduction in strength for water conditioned specimens. However, no microstructural difference in type or intensity of internal damage was observed for the three sample types.

Key words: *Polymer composites, durability, scanning electron microscopy (SEM)*

INTRODUCTION

Glass/polyester laminates are commonly used in boat building industry due to low density and low manufacturing costs especially when cost effective hand lay-up method is concerned. The disadvantage of this method is reduced stiffness due to high resin content and low structural quality of the material especially high void content [1,2]. Accordingly in modern ships made of glass, carbon and aramid/vinylester composites especially for the navy the traditional hand lay-up method is replaced by vacuum bagging or infusion process. Also when new, multilayer reinforcement are introduced in boat building the new methods should be considered.

Introducing new techniques requires skills and the result is not always positive [3,4]. Especially when penetration of the resin in vacuum process is not correct the mechanical properties of the laminate will be reduced when exposed in water environment [5-6]. Accordingly, it is necessary to characterize and compare the materials obtained using different methods and subjected to water exposure.

The aim of this study was to compare the efficiency of vacuum methods compared to the traditional hand lay-up based on the results of the mechanical and environmental tests. The comparison of the mechanical behaviour of materials in dry condition was reported in the previous publication [7]. In the present study the results of water immersion tests were outlined.

MATERIALS AND EXPERIMENTS

Laminates were made using unsaturated pre-accellerated vinyl ester urethane resin BUFA Atlac 580 ACT, (DSM Composite Resins). Catalyst was 1,5% Metox 50. Specimens were cured at room temperature for 24 hours.
Glass fibers were in the form of fabric consisting of chopped strand mat (500g/m^2) stitched with a 0/90^o UD stitched fabric (860 g/m^2).
Laminate plates were fabricated at motor boat building plant Galeon, Gdańsk, Poland using three methods hand lay-up, vacuum bagging, infusion described in [7,8]. Laminate thicknesses obtained were respectively: 3,8mm, 2,6 mm 2,7 mm.

In order to study the effect of water immersion on the mechanical characteristics of the three laminate type the sides of the specimens prepared for bending tests were protected by epoxy paint to prevent fast water sorption through the edges. Water sorption accelerated tests were made based on standard ASTM [9] by immersion in water at 70^{0}C for 50 days, which corresponds to the exposure of 30 years at 19^{0}C. Mechanical behaviour was characterized using three point bending test and interlaminar shear test. In order to study microstructure of the materials sections were polished and observed using scanning electron microscope Philips-FEI XL 30 ESEM

RESULTS AND DISCUSSION

Microstructure was compared in dry condition [7] and following water exposure. Fig. 1 shows the typical defects which developed in the laminates under the influence of water molecules absorbed into the surface layer of the laminate. To be noted is the network of debondings which was formed at fibre matrix interface due to reduced interfacial adhesion. No difference was observed in the types or intensity of water induced damage depending on the manufacturing route.

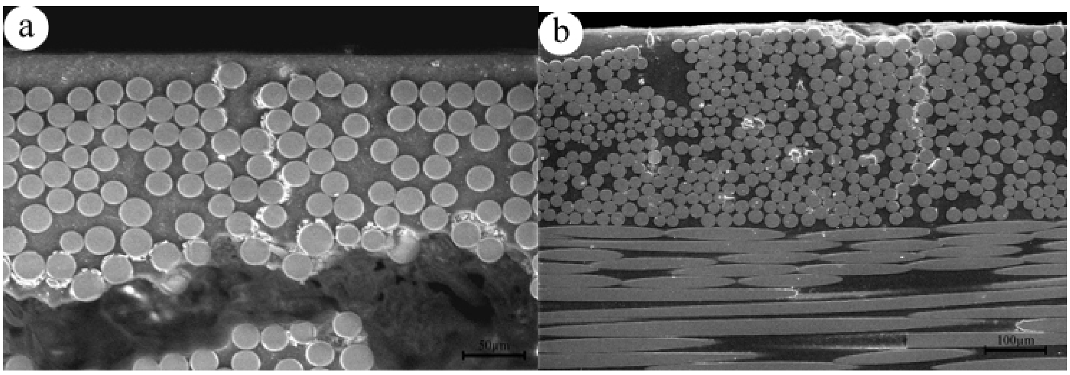

Fig. 1. Network of debondings and micro-cracks in the surface layer of the laminate subjected to water exposure at 70^{0}C for 50 days a/ hand lay-up method b/ infusion method

However, significant reduction (40-50%) was observed in the flexural strength (Table 1) due to water exposure. Specimens manufactured by infusion and vacuum bagging methods suffered slightly less degradation (ca. 40%) than the hand-lay-up (ca 50%).

Graphs showing flexural stress-strain curves for "wet" specimens manufactured using three methods are illustrated in Fig. 2. Table 1 illustrates significant reduction in deflection at fracture (increased brittleness due to absorbed water) which depends on the specimen thickness, slightly less (40%) for thick (h=3,8 mm) laminate compared to 60% for thinner (h=2,7mm) laminate manufactured using infusion.

Table 1. *Flexural strengths and deflection at fracture of laminates manufactured using three methods in dry condition and following exposure in water*

Manufacturing method		Deflection at fracture [mm]	Max. Stress [MPa]	% reduction
Hand lay-up	dry	10,46	333	
	wet	6,13	177	47
Vacuum bagging	dry	17,43	369	
	wet	8,7	194	48
infusion	dry	20,03	370	
	wet	8,25	225	40

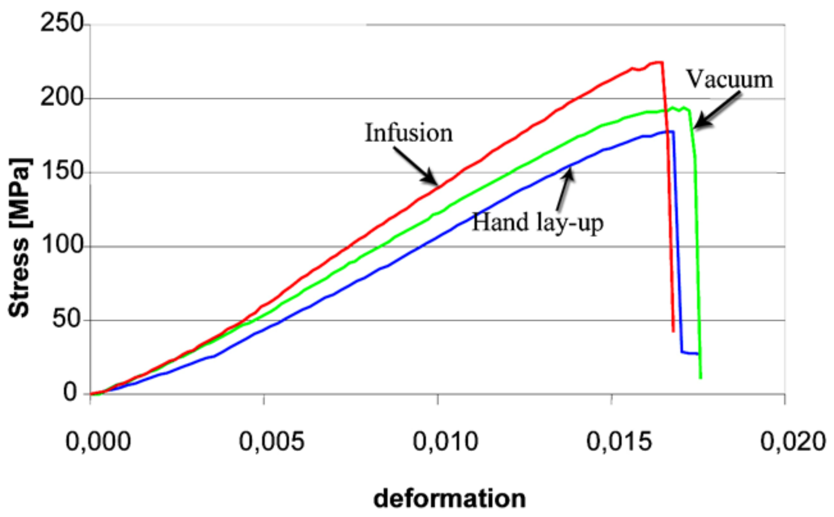

Fig. 2. Flexural stress-strain curves for specimens immersed in water ("wet") manufactured using three methods

Fig. 3a-c shows the reduction in flexural behaviour due to water exposure in short beam – interlaminar shear test. The results are summarized in Fig. 3d. The reduction of interlaminar shear strength is ca. 15%-25%. The smallest reduction is for hand lay-up, the highest for infusion. This unexpected result is due to difference in sample thickness (ca. 30% higher for the laminate made by hand lay-up) and equal exposure times so finally the internal regions of the thicker laminate were much less affected than the thinner.

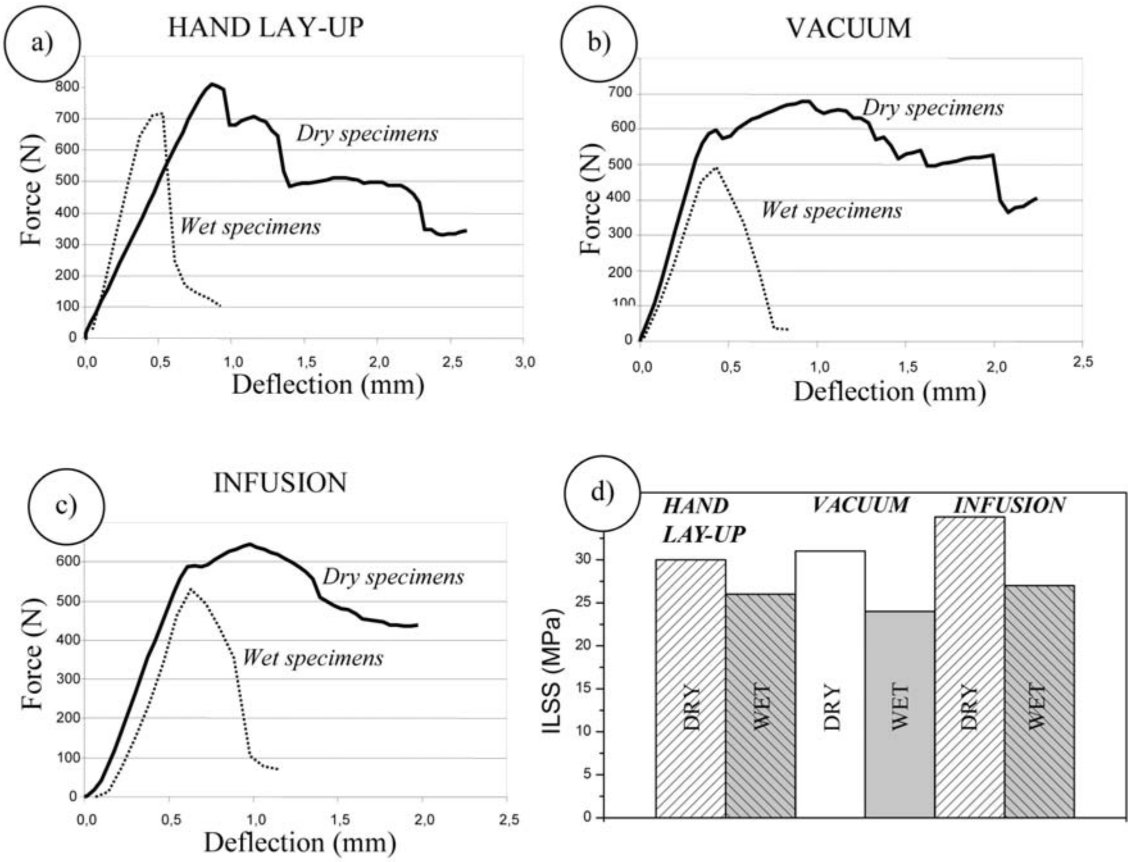

Fig. 3. Results of short beam test. Reduction in interlaminar shear strength due to water exposure

CONCLUSIONS

Mechanical behaviour was compared for glass/ polyester laminates manufactured in the boatbuilding plant using three methods: hand lay-up, vacuum bagging, infusion and subjected to water immersion test.

In conclusion we may say that improved strength and stiffness of the materials obtained due to advanced manufacturing methods gives only slightly higher resistance to water induced degradation. Despite higher strengths obtained for "infusion samples" in dry condition reduction in flexural strength of conditioned samples is only 10% less for infusion and vacuum bagging (40% compared to 50% for hand lay-up). Interlaminar shear strength is reduced by 15-25% for the three methods.

Acknowledgements

Authors wish to thank Michał Stempa and Włodzimierz Gawlak former students of Gdansk University of Technology for their contribution to this work.

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