10th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2006, Barcelona-Lloret de Mar, Spain, 11-15 September, 2006

ASPECTS CONCERNING THE STRAINS AND STRESSES DEVELOPED IN THE REAR PLATE OF A MOTOR BOAT HULL

Camelia CERBU
"Transilvania" University of Brasov
B-dul Eroilor 29, 500036 Brasov,
Romania

Dorin ROŞU
S.C. Compozite S.R.L.
Str. Plevnei 18, 500187, Brasov
Romania

ABSTRACT
In this paper, the rear plate of a motorboat hull made of randomly E-glass fibres reinforced polymeric resin is analysed. A numerical model of the rear plate of a motorboat hull is proposed by using the method of finite elements. Stresses and strains occurred due to the action of the drag force developed by the motor of the boat, were analysed in case of four kinds of composite materials. Then, the strains about three directions in five points of the rear plate of the motorboat hull made of E-glass / Polylite 440-M880 composite, were measured by using five bonded strain gauges. The experimental strains and theoretical strains measured in the same points on the numerical model, were compared in case of the drag forces of 294.3 N and 392.4 N. The experimental errors were less than 5-6 % (only four errors were between 5 and 6 %). The results lead us to the conclusion that the theoretical model of the rear plate, may be used to optimise it. From rigidity point of view, it is shown that E-glass / epoxy composite material should not be used to manufacture the motorboat hull.
Keywords: composite, stress, strain, finite elements

1. INTRODUCTION
It is known that glass fibre reinforced polymers are widely used to manufacture the hull of the boats. Herein, the states of strain and stress developed in the rear plate of a motor boat hull are analysed from theoretical and experimental points of view. Finally, the theoretical and experimental values are compared. We note that S.C. *Compozite* S.R.L. of Braşov (Romania) manufactures the motor boat tested (Fig. 1) within this paper.

2. WORK METHOD

2.1. Theory
The first of all, theoretical research [1] concerning the states of stress and strain inside the rear plate of the motor boat hull was considered. From theoretical point of view, a numerical model of the rear plate of a motor boat hull (Fig. 3) was proposed by using the method of the finite elements. To model the rear plate Shell43 elements are used because this member is made of randomly reinforced E-glass / polyester Polylite 440-M880 whose $E = 9081 MPa$ [1, 2]. It is known that randomly reinforcing is used to obtain a composite material whose elastic characteristics are the same about any direction (isotropic material). This means that the element Shell43 is justifiably chosen. Solid45 elements are used for the holding plate of the motor whose drag force acts upon the rear plate of the motor boat hull. Finally, 28926 *nodes* and 32985 *elements* were obtained for the numerical model of the rear plate

of the motor boat hull. Boundary conditions and the external drag force developed by the motor, are sown in the Fig. 2.
Stresses and strains (Fig. 4-6) occurred due to the action of the maximum drag force $(F_{\max} = 1589{,}22\,N)$ developed by the motor of the boat, were analysed.

Figure 1. Motor boat hull

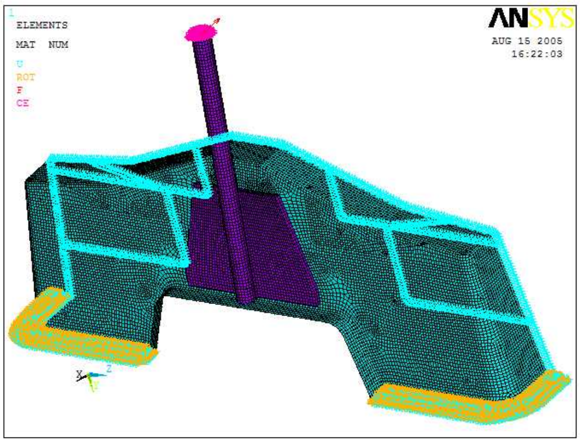


Figure 2. Boundary conditions and loading

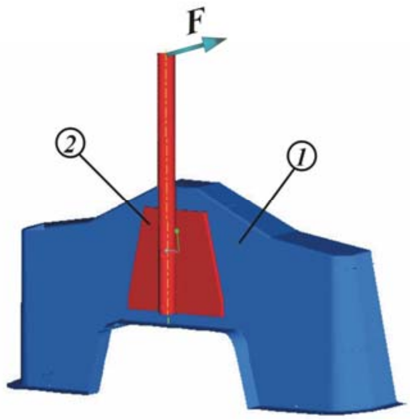


Figure 3. Geometrical model and loading scheme: 1- rear plate of the motor boat hull; 2 – holding plate of the motor

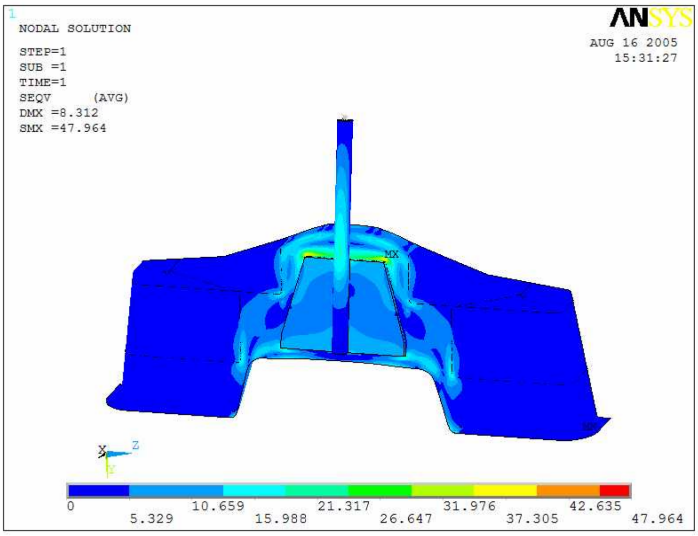


Figure 4. Equivalent stress $\sigma_{eqv.}$ (Von Misses)

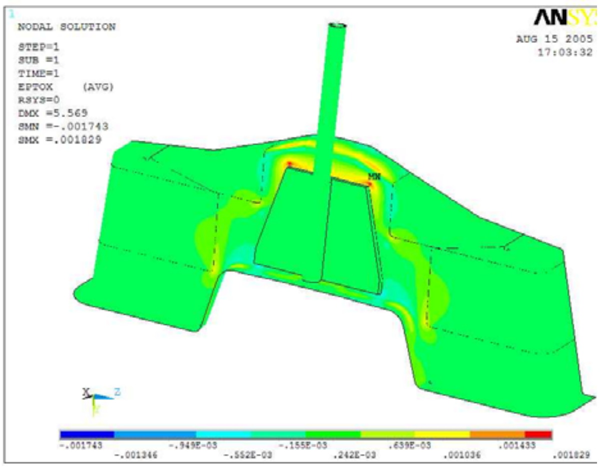


Figure 5. Normal strain ε_x

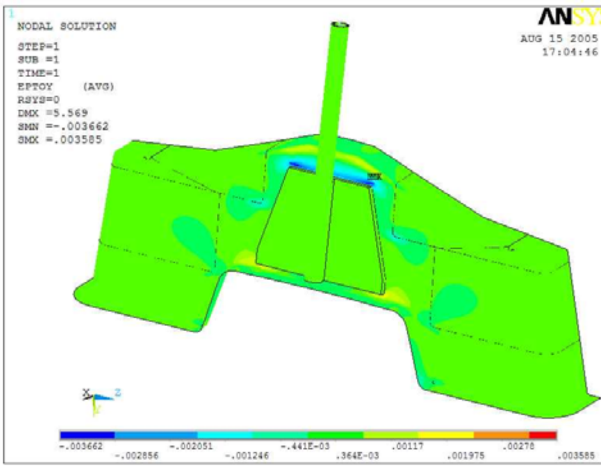
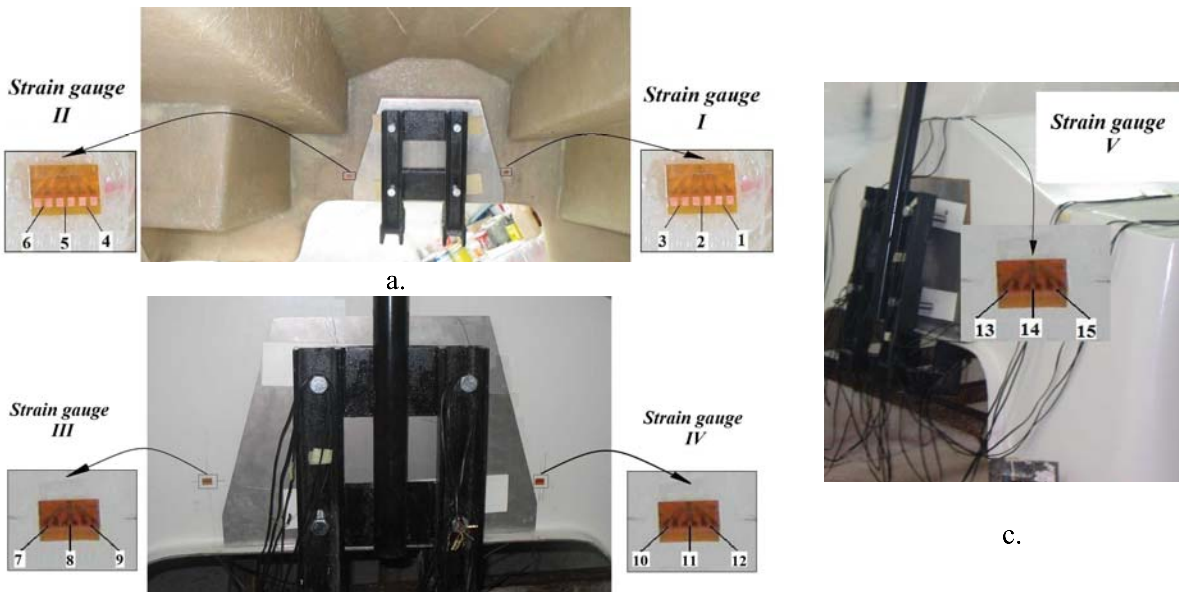


Figure 6. Normal strain ε_y

2.2. Experimental
To check the numerical model proposed, the strains about three directions in five points of the rear plate of the motor boat hull made of E-glass / Polylite 440-M880 composite, were measured by using five bonded strain gauges. Fifteen strains were experimentally recorded for each value of the external drag force: 98.1 *N*, 196.2 *N*, 294.3 *N* and 392.4 *N*, respectively.
The test stand shown in the figure 1 was used to experimentally analyse the state of strains occurred in the rear plate. The temperature was 22–24 ℃ while the humidity was approximately 60 % during the test.
To determine experimentally the state of strains developed at an arbitrary point of the rear plate, the method of electrical strain measuring was used. This method is based on the principle of the conversion of the mechanical strains in variations of the electrical resistivity. To measure the strains we used the quarter-bridge arrangements by using: five bonded strain-gauges which may measure the strains about three directions (Fig. 7). The gauges were manufactured by *Micro-Measurements Division* – Raleigh, Carolina de Nord, U.S.A and they have the following characteristics: electrical resistivity 120,0Ω ± 0,4% (24 ℃), the parameter (constant) of the gauge k = 2,11±0,5% (24 ℃), transverse sensitivity (+0,8±0,2) %, measure length 5 *mm*, the limit of the strain measured 5 %; *Hottinger HBM* test bridge.



b.

Figure 7. Position of the strain gauges on the hull of the motor boat: a- on the inner side; b,c – on the outside

The strain about one measure direction of the bonded strain gauge (quarter-bridge arrangement) was computed by using the formula [3]:

$$\varepsilon = 4 \cdot \frac{\Delta U_e}{U_i \cdot k} = 4 \cdot \frac{\Delta U_e}{4 \cdot 2{,}11} = \frac{\Delta U_e}{2{,}11} \left[\frac{\mu m}{m} \right]. \qquad (1)$$

where $U_i = 4V$ represents the power-supply voltage; ΔU_e - the output voltage and $k = 2{,}11$ is the parameter of the gauge.

3. RESULTS AND DISCUSSIONS
The experimental strains and theoretical strains measured in the same points on the numerical model, were compared in case of the drag forces of 294.3 *N* and 392.4 *N* (Table 1). The experimental errors were less than 5-6 % (only four errors were between 5 and 6 %) as it is shown in the figure 8.
The final results concerning the errors of the experimentally measure show us that the numerical model proposed within this paper is correct. Therefore, by changing the mechanical characteristics for another material, we shall analyse the states of strains and stresses for the new model.

Table 1: Theoretical and experimental values of the strains

	Force [N]			
	392,40		**294,30**	
	Strain ε [x10^{-5}]			
	Theory	***Experimental***	***Theory***	***Experimental***
TER1	-3.76690	-3.5974	-2.82518	-2.7057
TER2	-0.74477	-0.7727	-0.55858	-0.5799
TER3	-6.67250	-6.3475	-5.00438	-4.7612
TER4	-6.34690	-5.9883	-4.76018	-4.4941
TER5	-0.80116	-0.8359	-0.60087	-0.6267
TER6	-4.85840	-4.7209	-3.64380	-3.5396
TER7	3.28750	3.4788	2.46563	2.6096
TER8	0.29742	0.2893	0.22307	0.2167
TER9	4.04720	3.8493	3.03540	2.8864
TER10	6.42890	6.1049	4.82168	4.5763
TER11	0.40980	0.4287	0.30735	0.3216
TER12	2.32170	2.4208	1.74128	1.8160

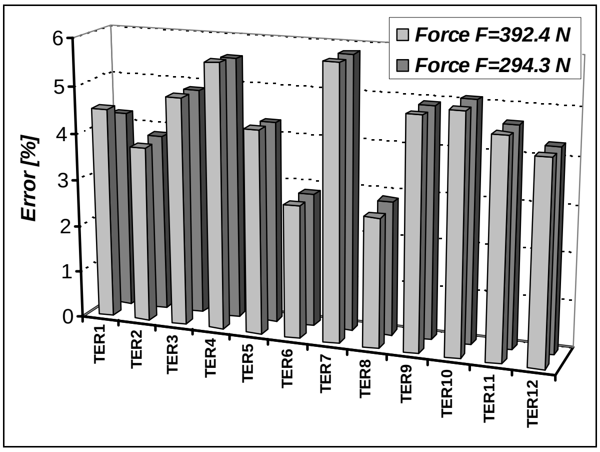


Figure 8. Comparison of the theoretical and experimental strains

Finally, we analyse the stiffness of the rear plate in case of the others composites: E-glass / polyester Heliopol 8431 ATX $(E = 9381\ MPa)$, E-glass / epoxy LY554 $(E = 5825\ MPa)$, E-glass / vinyl-ester Atlac 582 $(E = 7909\ MPa)$.

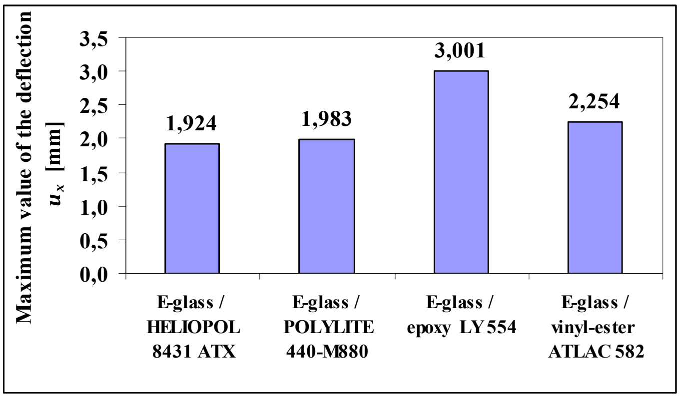


Figure 9. Maximum value of the deflection u_X for the rear plate in case of the composites analysed

5. CONCLUSIONS

Comparing of the theoretical strains and experimental strains leads us to the conclusion that the theoretical model of the rear plate, may be used to optimise it in the future, by taking into account the environmental effects on the composite material.

Analysing the maximum value of the deflection u_X of the rear plate of the motor boat hull in case of the composite materials analysed, we may note that E-glass / Heliopol 8431 ATX or E-glass / Polylite 440-M880 should be used to manufacture the member tested. On the other hand, the environmental effects were not considered.

6. REFERENCES

[1] Cerbu Camelia: Researches concerning structural optimization of some members made of composite materials loaded under aggressive environmental effects, Doctoral thesis, University “Transilvania” of Brasov, Romania, 2005,

[2] Cerbu Camelia, Curtu I.: *Aspects concerning environmental effects on the glass-reinforced polymers*, Proceedings of the 9th International Research / Expert Conference “Trends in the Development of Machinery and Associated Technology” TMT 2005, ISBN 9958-617-28-5, Antalya, Turcia, 26 – 30 septembrie 2005, p. 1451-1454,

[3] Szava I., Ciofoaia V., Luca-Motoc Dana, Curtu I.: Metode experimentale în dinamica structurilor mecanice, Editura Universității “Transilvania” din Brașov, ISBN 973-9474-40-3, 2001.