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# RESEARCHES CONCERNING STRUCTURAL OPTIMIZATION OF THE REAR PLATE OF A MOTORBOAT HULL MADE OF COMPOSITE MATERIALS

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## ABSTRACT
*It is known that the moisture content may affects the mechanical characteristics of the composite materials. The principal objective of this paper is to optimise from material point of view, the rear plate of a motorboat hull made of composite material. An additional criterion of optimisation concerning the conservation of the mechanical properties under the action of the moisture, was considered. Three E-glass reinforced composites were considered to analyse mechanical behaviour of the rear plate of a motorboat hull. From material point of view, the structural optimization of the rear plate of the motorboat analysed, leads to the conclusion that E-glass / polyester Polylite 440-M880 or E-glass / vinyl-ester Atlac 582 should be used to manufacture this member.*
**Keywords:** composite, finite elements, optimisation, environment, stiffness.

## 1. INTRODUCTION
To use the full potential of these composite materials, their response to environmental effects (moisture, temperature, thermal cycle etc.) must be known. In the previous papers [1, 2, 3, 4] it was shown that the mechanical characteristics (tensile strength, flexural modulus $E$ and flexural stress $\sigma_e$ to the elastic limit) decreases after 9200 *hours* of immersion in water and natural seawater (from *Black Sea*). Some experimental results published in those papers will be used to show the advantages of the E-glass / polyester Polylite 440-M880 and E-glass / vinyl-ester Atlac 582.
The stiffness of the rear plate of a motor boat hull is analysed in case of the undamaged and damaged composite materials. The conservation of the stiffness under the action of the water and seawater is an additional criterion used to optimise the rear plate of a motor boat hull. We note that S.C. *Compozite* S.R.L. of Brasov (Romania) manufactures the motor boat (Fig. 1) analysed within this paper.

## 2. WORK METHOD

### 2.1. Theory
A numerical model of the rear plate of a motorboat hull (Fig. 2) was proposed by using the method of finite elements. Stresses and strains occurred due to the action of the drag force $\left(F_{\max} = 1589{,}22\,N\right)$ developed by the motor of the boat, were analysed. To model the plate Shell43 elements are used because it is made of randomly E-glass fibres composites. It is known that randomly reinforcing is used to obtain a composite material whose elastic characteristics are the same about any direction.

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. Figure 2 shows boundary conditions and the external drag force developed by the motor.

The first of all, we analysed the results concerning stresses and strains developed in the rear plate of the motor boat hull made of E-glass / polyester Polylite 440-M880 $(E = 9081 MPa)$. Herein, we show only the equivalent normal stress $\sigma_{ech.}$ by using *Von Misses theory* (Fig. 3), normal strains $\varepsilon_x$ (Fig. 4). One may observe that the normal stresses do not exceed the elastic limit of the composite (table 1).

*Figure 1. Motor boat hull*

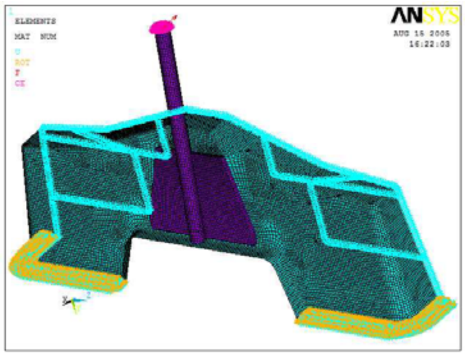

*Figure 2. Boundary conditions and loading*

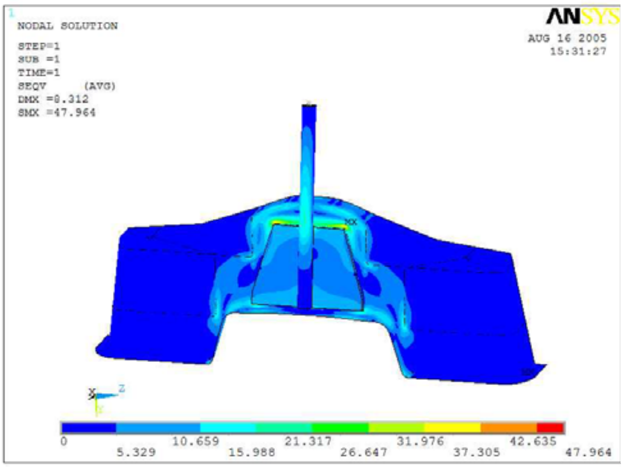

*Figure 3. Equivalent normal stress $\sigma_{ech.}$ (Von Misses) for the numerical model of the rear plate (E-glass / Polylite 440-M880- $E = 9081 MPa$ )*

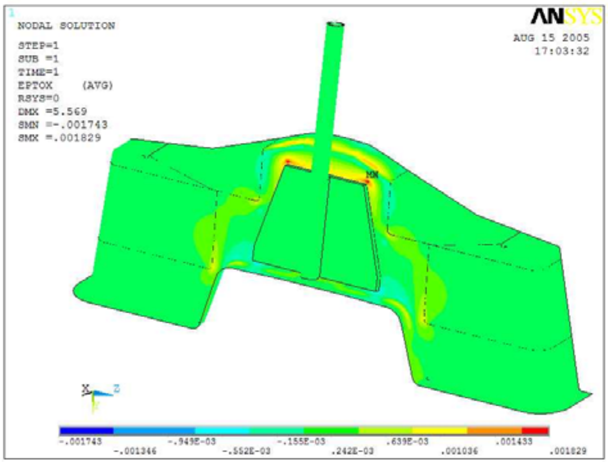

*Figure 4. Normal strain $\varepsilon_x$ (E-glass / polyester Polylite 440-M880 - $E = 9081 MPa$ )*

The problem that arises is how the degradation of the composite material due to the moisture absorption, acts on the stiffness of the rear plate.

### 2.2. Experimental results

Experimental investigations [1, 2, 3] concerning environmental effects on the mechanical behaviour of the composites involved were made. Figure 5 shows us the variations of deflection *v* of the midpoint of the flexural specimen with respect to the applied force *F (E-glass / epoxy LY 554)*. Analysis of *F*-*v* curves lead us to the conclusion that the flexural modulus *E* and flexural stress $\sigma_e$ at the elastic limit, decrease due to the moisture absorption (Table 1).

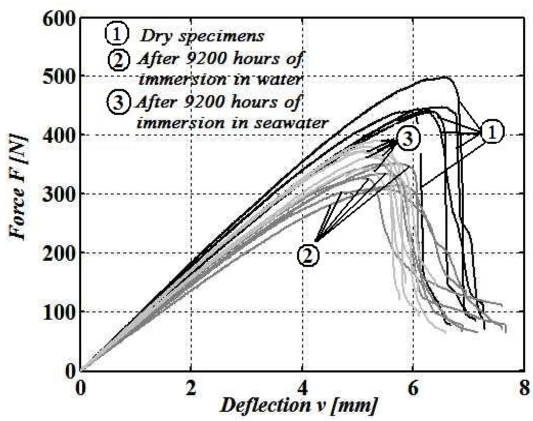


*Figure 5. Variation of the deflection v with respect to the force F (E-glass / epoxy LY 554)*

*Table 1. Effects of the water and seawater on the flexural modulus E and flexural stress $\sigma_e$ [1, 3]*

| | **E-glass / Polylite440-M880** | | **E-glass / epoxy LY554** | | **E-glass / vinyl-ester Atlac 582** | |
|---|---|---|---|---|---|---|
| | ***E*** [*MPa*] | $\sigma_e$ [*MPa*] | ***E*** [*MPa*] | $\sigma_e$ [*MPa*] | ***E*** [*MPa*] | $\sigma_e$ [*MPa*] |
| Dry material | 9081 | 159 | 5825 | 128 | 7909 | 139 |
| After 9200 *hours* of immersion in water | 8225 | 138 | 4543 | 88 | 7380 | 122 |
| After 9200 *hours* of immersion in seawater | 8164 | 130 | 5258 | 98 | 7358 | 123 |

Because the greatest values of the displacement are about *Ox* direction, the changes of the stiffness was analysed by comparing the maximum displacement $u_x$ about that direction as will be shown in the next section.

## 3. RESULTS AND DISCUSSIONS

Since the conservation of some mechanical characteristics of the composite materials tested, had already been analysed, it was easy to apply the experimental results to the numerical model proposed. The results concerning the displacement $u_x$ of the rear plate in case of the E-glass / Polylite 4440-M880 undamaged (Fig. 6) may easily compared with the results obtained in case of the damaged composite after 9200 *hours* of immersion in water (Fig. 7).

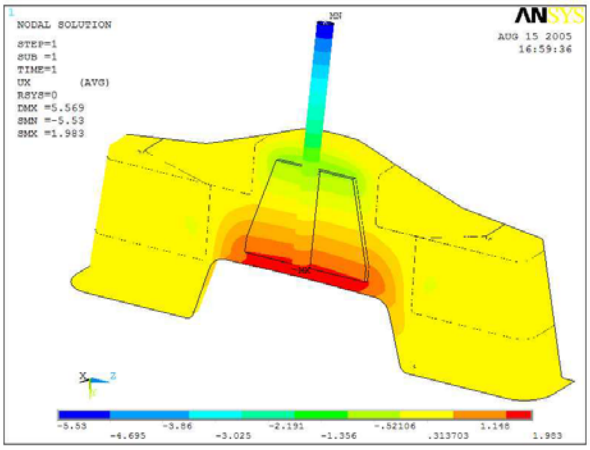


*Figure 6. Displacement $u_x$ (E-glass / polyester Polylite 440-M880 - $E = 9081\,MPa$ )*

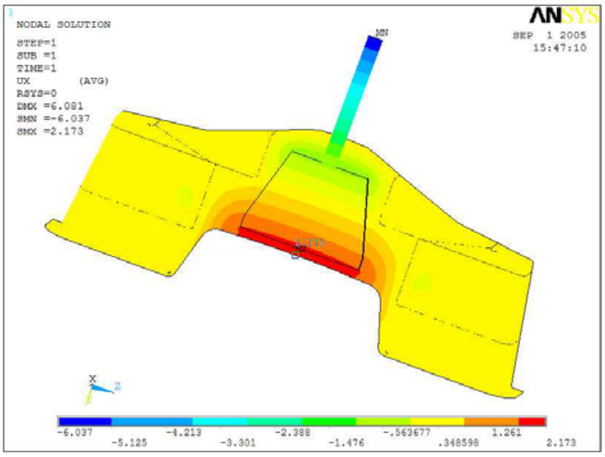


*Figure 7. Displacement $u_x$ after 9200 hours of immersion in water (E-glass / polyester Polylite 440-M880 - $E = 8225\,MPa$ )*

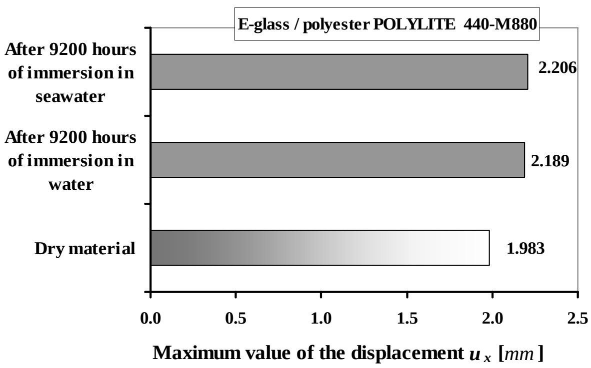


*Figure 8. Maximum value of the deflection $u_x$ for the rear plate (E-glass / Polylite 440-M880)*

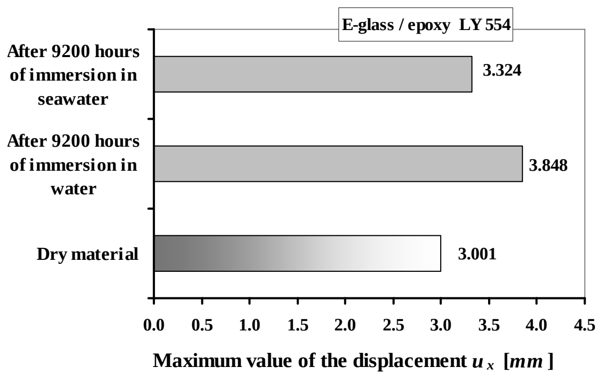


*Figure. 9. Maximum value of the deflection $u_x$ for the rear plate (E-glass / epoxy LY 554)*

Since the modulus of elasticity decreases due to the action of the water and seawater (table 1), the stiffness of the rear plate also decreases. The maximum value of the displacement $u_X$ of the rear plate, was graphically analysed (Fig. 7-9) in case of all composite materials tested, before and after 9200 *hours* (≈ 13 months) of immersion in water and natural seawater (from *Black Sea*).
Analysing the above graphics the following important remarks are noted:

- The effects of the water and seawater on the stiffness of the rear plate analysed are different in case of all composite materials considered.
- The greatest value of the maximum displacement $u_X = 3.848\,mm$ (Fig. 8) is observed in case of the E-glass / epoxy LY 554 composite damaged due to the water absorption. The conservation of the stiffness of the motor boat hull is not good when E-glass / epoxy LY 554 composite is used to manufacture this member.

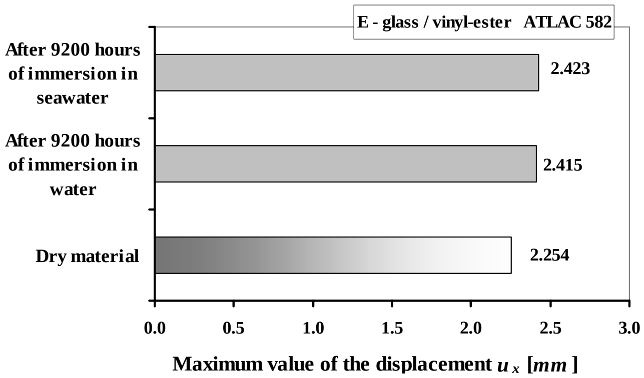


*Figure 10 – Maximum value of the deflection $u_X$ for the rear plate (E-glass / vinyl-ester Atlac 582*

- The maximum displacement $u_X$ in case of the E-glass / Polylite 440-M880 undamaged (Fig. 7) is approximately equal to half of the maximum displacement $u_X$ in case of the E-glass / epoxy LY 554 damaged (Fig. 8) due to the water absorption.
- The effects of water and seawater on the stiffness of the member analysed made of E-glass/vinyl-ester Atlac582 are approximately the same (Fig. 10).
- Maximum displacement $u_X = 2.2$ in case of the E-glass / Polylite 440-M880 damaged (Fig. 7) while $u_X = 2.4$ in case of E-glass / vinyl-ester Atlac 582 damaged (Fig. 9).

## 4. CONCLUSIONS

Finally, some important conclusions of this paper are noted:

- Since the flexural modulus *E* of the composite materials analysed decreases, it follows that the stiffness of these composites decreases by the same ratio (between 5 % and 20 %).
- The E-glass / polyester Polylite 440-M880 and E-glass / vinyl-ester Atlac 582 are recommended as composite materials in case of water or seawater environment. In particular case, these materials may be used to manufacture the hull of the motor boat analysed.
- From material point of view, the structural optimisation of the rear plate of the motorboat analysed, leads the authors, to the conclusion that *E-glass / polyester Polylite 440-M880* must be used to manufacturer this member. The principal reason was the conservation of the strength and stiffness under the action of the environmental effects in case of that composite material. This criterion was considered in addition to the high-strength criterion and high-stiffness criterion.
- E-glass / epoxy LY 554 composite materials is not recommended in wet environment due to the degradation of the stiffness under the action of water and seawater.

## 5. REFERENCES

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