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TRANSOM STRENGTHENING OF A RIGID INFLATABLE BOAT (RIB) TO INCREASE PROPULSION POWER

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Abstract: *When in use, boats could be modified provided that their safety of construction is not affected. For this purpose, verification calculations are carried out for the elements affected by changes and when ascertained that safety of construction is not ensured, adequate strengthening is made. This article describe that kind of strengthening to the transom of a rigid inflatable boat (RIB), following the replacement of the original engine of 90 HP by one of 130 HP. Strength calculations for transom made of sandwich type composite material, were made using COSMOS/M software and laminated plate type elements SHELL4L.*
Keywords: *composite material, small craft, scantling, transom*

1. INTRODUCTION

During the use of boats made of composite materials, these could be subject to modifications such as increase of length, breadth or depth, increase of displacement, modification of superstructure, rise of power, etc., which could impact upon hull strength and for this reason the verification of the resistance of structural elements affected by modifications is necessary, and if not suitable, these elements shall be strengthen.
Such kind of modification was carried out to a RIB (Rigid Inflatable Boat), to which the propulsion outboard engine type EVINRUDE E90DSL of 90 HP was replaced by a new engine type EVINRUDE E130DSL of 130 HP (but keeping same propeller pitch thus, at equal rate of revolutions, the boat speed is not modified) in order to increase boat acceleration from stop for decreasing the transitory regime to reach the aquaplanning speed of towed water skiers.
The particulars of this boat are given in Table 1.

Table 1: Boat particulars

Craft Type	RIB
Design Category	C
Material	GRP single-skin laminates and GRP sandwich composites
Displacement, m_{LDC}	1200.00kg
Length of Hull, L_H	4.52m
Hull Beam, B_H	2.20m
Depth of Bulkhead, D_b	1.16m
Maximum speed, V	40.00kts

The above-mentioned modification could be accepted if we prove that the transom strength is sufficient to stand the new efforts introduced by the 130 HP engine and the boat stability and maneuverability are ensured.
Transom strength was verified hereinafter through direct strength calculations based on finite element method and taking into account the international standard ISO 12215-5: 2008 – Small kraft. Hull construction and scantlings. Part 5: Design pressures for monohull, design stresses and scantlings determination.

2. STRENGTH ASSESSMENT OF NON-MODIFIED TRANSOM

The transom of initial boat, having the shape and dimensions according to Figure 1, is built of sandwich type material as shown in Figure 2, with 5 alternate layers of GRP and teak wood (MULTI-LAYER 1) whose dimensions are given in Table 2.

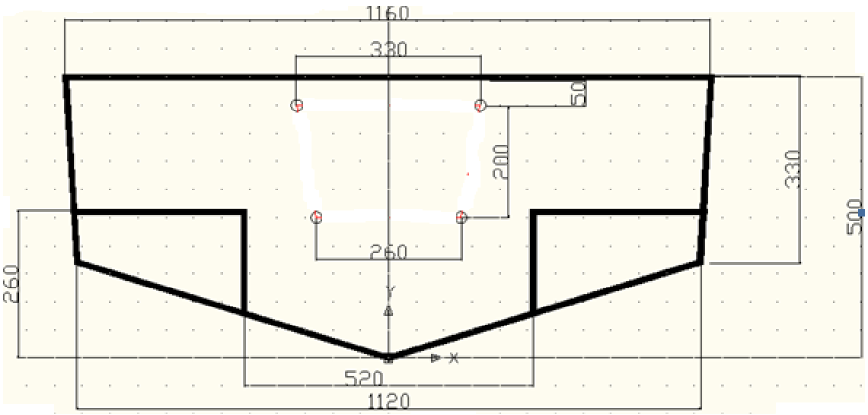

Figure 1: Initial transom

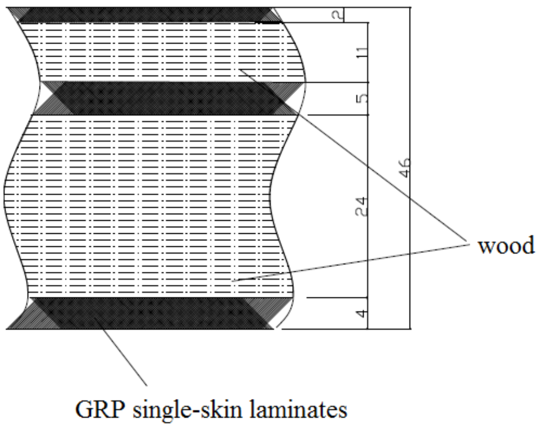

Figure 2: Structure of transom material

Table 2: Mechanical and physical characteristics of materials: teak wood, GRP and steel

Characteristic	m.u.	Teak wood	GRP ISO-12215-5	Steel
E1	MPa	10500 - 15600	45000	210000
E2	MPa	3000	12000	210000
E3	MPa	1000	10000	210000
μ12		0.32	0.32	0.32
μ23		0.08	0.32	0.32
μ31		0.06	0.32	0.32
G	MPa	5000	4800	80000
Ultimate tensile strength	MPa	95 - 155	95	4000
Ultimate compression strength	MPa	48 - 91	95	4000
Ultimate flexural strength	MPa	86 - 170	140	4500
Density	kg/m3	400	1900	7800

The calculation of forces acting on transom is shown thereinafter:

- Engine weight, G =1840 N – is uniform distributed on 4 fixing bolts;
- Steady point thrust on propeller was determined according to BV Rules, Pt. E, Ch. 14, Sect.2: P=20000 N

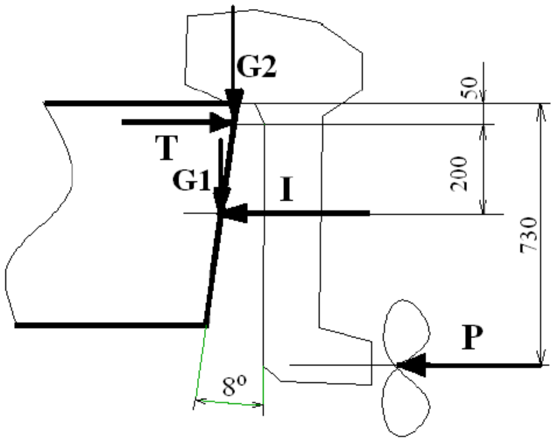

Figure 3: Diagram of efforts acting on transom

- Efforts T and I are distributed on each of 4 fixing points on transom as follows:

  on each of 2 bolts on upper line:

  T/2=23935.35 N

  G2/2=460 N

  on each of 2 bolts on lower line:

  I/2=33935.35 N

  G1/2=460 N

Strength calculation was performed with COSMOS/M software.

As finite element mesh (FEM), SHELL4L type of laminated plates were used.
Number of elements: 14920.
Number of nodes: 16110.

Bearing constraints:

- Simply supported in the longitudinal and vertical direction of the boat:
  - on the boundary of transom: bottom and sides
  - on the boundary of longitudinal girders
- Constraint of symmetry in the symmetry axis (angle of rotation around the vertical symmetry axis is zero).

Results of calculations are shown in Table 3 and in the diagram of Figure 4.

Table 3: Maximum equivalent stresses on layers

Layer	Thickness [mm]	Material	Node	Node position	Equivalent stress, σ_{vM} [MPa]	Permissible stress [MPa]
1	4	GRP	11684	Corresponding to the bolt on the lower row	68.36	47.0
2	24	Wood	11684	Corresponding to the bolt on the lower row	42.78	47.5
3	5	GRP	11684	Corresponding to the bolt on the lower row	49.77	47.0
4	11	Wood	11684	Corresponding to the bolt on the lower row	44.91	47.5
5	2	GRP	11684	Corresponding to the bolt on the lower row	77.01	47.0

Maximum transom deflection is 4.54 mm and is located in center line, where transom intersects deck.

Following assessment of these results, we find out that actual stresses in transom are greater than safe working stress in points where efforts from engine are transmitted. And, in consequence, strengthening of the transom was necessary.

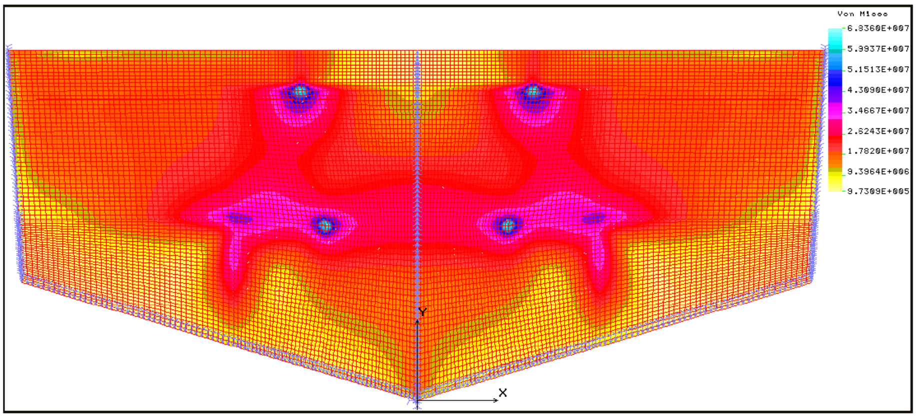

Figure 4: Diagram of von Mises equivalent stresses [Pa] in 1st layer – in case of non-modified transom

3. STRENGTH ASSESSMENT FOR STIFFENED TRANSOM

In order to have satisfactory strength in new working conditions with propulsion engine of 130 HP, the boat transom was stiffened as shown in Figure 5, as following:

- one stiffener made by two layers of wood and stainless steel in the central area, outside the boat,
- two stiffeners of stainless steel, inside the boat.

These stiffeners have been glued together and on the transom by a polyurethane glue for naval use.

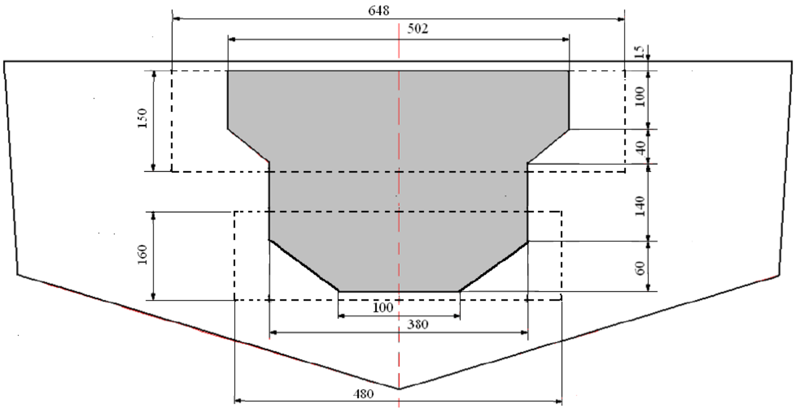

Figure 5: Transom stiffened area, by doubling with wood and stainless steel (central area in dark color – on the outside) and stainless steel stiffeners (doted areas – inside)

All structural elements of the transom, materialize in 4 laminates, as shown in Figure 6 and Table 4, situated in different places, dependent on overlapping of stiffeners with initial transom, see Figure 7.

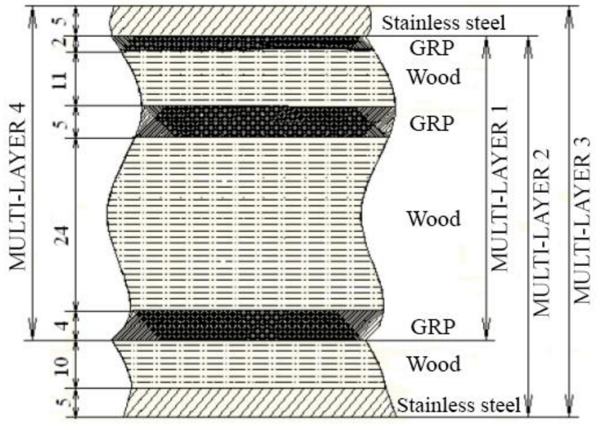

Figure 6: Structural layers of the transom

Table 4: Type of lamination for surfaces

Laminate type	Multi-layer 1	Multi-layer 2	Multi-layer 3	Multi-layer 4
Surfaces	4,5,6,7,9,11,13,49,50, 51,52,16,17,18,27,28, 29,30,32,36,53,54,55, 56,57,58,40,41	19,42	2,3,26,27,1,24,20,43	8,10,21,14,23,15, 38,46,37,44,31,33

Strength calculation was performed with COSMOS/M software.

As FEM, SHELL4L type of laminated plates were used.
Number of elements: 19026.
Number of nodes: 11043.
External efforts were applied on outside stainless steel plate.

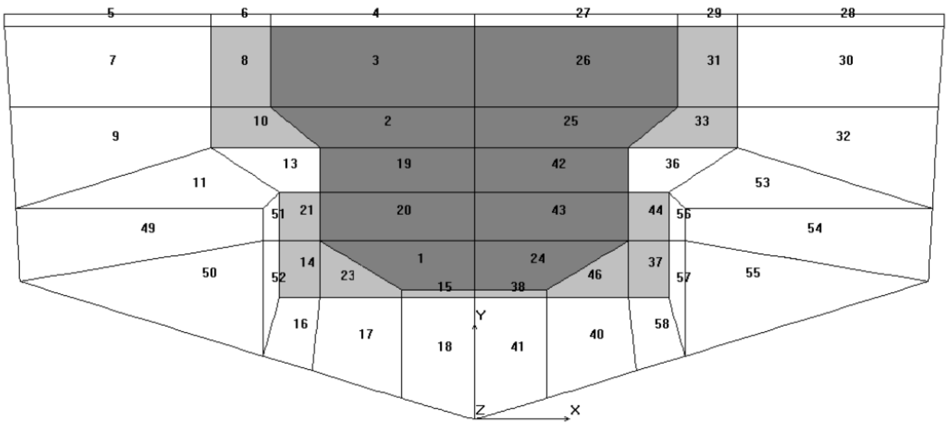

Figure 7: Transom meshing surfaces

Bearing constraints:

- Simply supported in the longitudinal and vertical direction of the boat on the exterior perimeter of transom, bottom and sides;
- Simply supported in the longitudinal direction of the boat on the boundary of longitudinal girders;
- Constraint of symmetry in the symmetry axis (angle of rotation around the vertical symmetry axis is zero).

Results of calculations are shown in Table 5 and in the diagrams of Figures 8 and 9.

Table 5: - Maximum equivalent stresses on layers

Laye	Thickness [mm]	Material	Hot spot position	Equivalent stress σ_{vM} [MPa]	Permissible stress [MPa]
1	5	Steel	Corresponding to the bolt on the lower row	68.87	200
2	2	GRP	Corresponding to the bolt on the lower row	7.48	47
3	11	Wood	Corresponding to the bolt on the lower row	10.80	47.5
4	5	GRP	Corresponding to the bolt on the lower row	8.22	47
5	24	Wood	Corresponding to the bolt on the lower row	21.79	47.5
6	4	GRP	Corresponding to the bolt on the lower row	17.51	47
7	10	Wood	Corresponding to the bolt on the lower row	47.35	47.5
8	5	Steel	Corresponding to the bolt on the lower row	40.48	200

Maximum transom deflection is 0.19 mm is located in center line, in way of the bolts on the lower row.

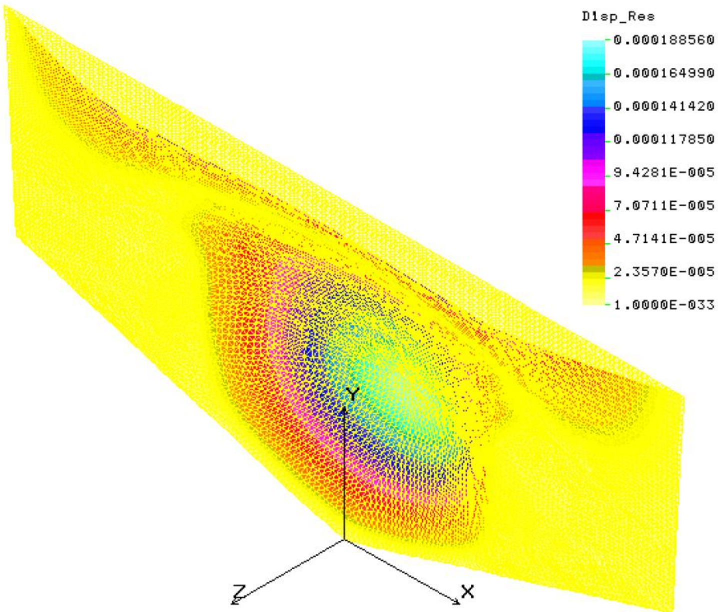

Figure 8:- 3D deflection of the transom in case 1

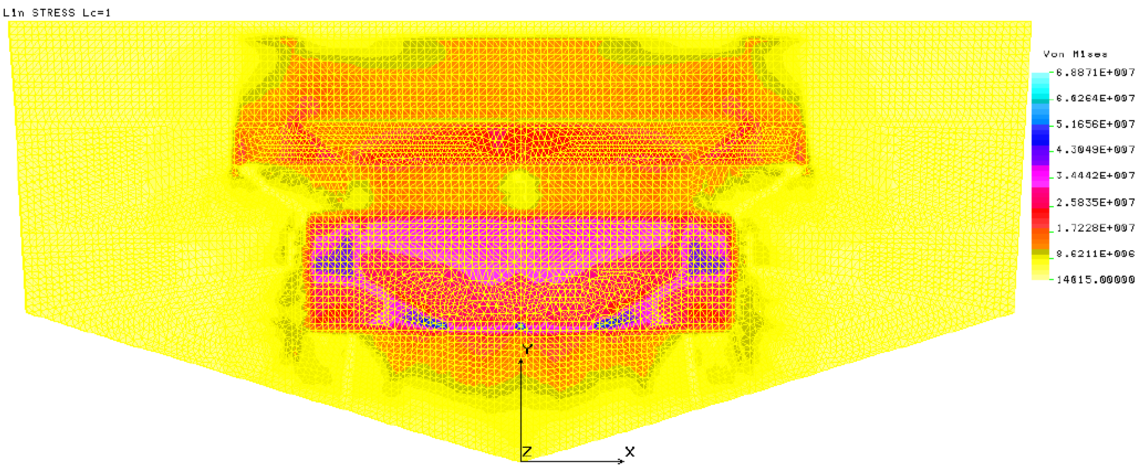

Figure 9:- Diagram of von Mises equivalent stresses [Pa] in 1st layer in case 1

By analyzing these results, we can conclude that actual stresses in transom are not greater than safe working stress and consequently it could be supposed that strengthen solution was effective.

Furthermore, after 2 years of use, owner of the boat is satisfied of boat behavior after modifications made, the stiffened structure of the transom having not permanent deflection, fractures or other mechanical damages due to greater forces transmitted by outboard engine.

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