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FINITE ELEMENT STRUCTURAL ANALYSIS ON PLANING BOATS DUE TO WAVE IMPACT

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SUMMARY

This paper introduces the recent development in the field of structural design for planing craft, where the longitudinal behaviour is analysed on a high performance FRP sandwich boat due to the wave impact. To carry on this analysis, the hull was studied by Finite Element Method. Real operating conditions were simulated in top speed, where stress and straing were calculated.

INTRODUCTION

It can't be denied that in the last years the search for high performances in planing boats in reinforced plastic has drastically modified the concept of design and construction of these boats, and nowadays sandwich constructions [1–2] using high strenght fibers [3], PVC foams, and vinylester resins take part in the day to day boatyard's technology. Presently, conservative constructions are inacceptable, and technological inovations mean at least the chance to compete in a market each time more challenging.

The difficulty of obtaining exact solutions for stresses and strains in this kind of structures is a well known fact, due to the complexity of the model, boundary and loading conditions and mechanical properties of materials. Lacking a trustful procedure for this analysis, experience and luck is the combination still used by designers and constructors. This can be seen in the great variety of structural dispositions found in these boats.

At this point, designers agree with the fact that nowadays there isn't a better way to design the structure of a high performance craft, except by using the finite elements method [4–5]. From an optimization point of view, this procedure has supplied the possibility of uniformization of the flexibility level of all the structure's elements [6] which would be impossible if only conventional formulations were used.

In this paper, we will exemplify the use of this procedure, analysing the longitudinal structure of a planing boat constructed using the sandwich system, simulating the condition in which this one cruise at high speed colliding with a characteristical wave. When this occurs the stresses and strains are evaluated for the entire structure. In a second stage, the most critical region of the bottom is discreated, where the longitudinal stiffeners stresses aer verified.

THE MODEL

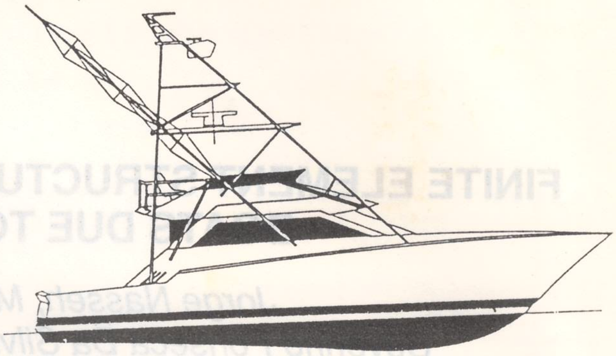
The sportfhiserman, 50 feet long, project of the American Tom Fexas, was selected for our study. It was constructed by the Mares Marazul shipyard, at Rio de Janeiro. Its main particulars are shown in Table1 and its side view in Figure 1.

The main reason for this model's choice was due to its advanced construction concept [7], low weight, great power and speed above 36 knots.

The hull is constructed in the sandwich system, extensively using fiberglass woven rovings, laminated with vinylester resin Derakane and rigid PVC foam Divinycell. The structural system is composed by 4 longitudinal stiffeners continuous from fore to aft and 4 structural bulkheads laminated in sandwich system under vaccum bag. Unidirectional tapes of fiberglass are used in addition to stiffener's flanges, chine and sheer.

TABLE 1: MAIN PARTICULARS

Length Overall	50.8 ft
Length of WL	41.3 ft
Breadth Moulded	15.9 ft
Design Draft	3.1 ft
Displacement	35000 lb
Power	1500 HP
Fuel Capacity	750 gal
Wate Capacity	250 gal
Speed	36 Knots



The intense use of woven rovings supplied a laminate of a very high resistence, that can be proven by the values of the composite material's mechanical properties, tested satisfying ASTM patterns, and listed in the Tables 2 and 3.

TABLE 2: FACES PROPERTIES

Tensile Strenght	47332 psi
Tensile Modulus	$1x10^6$ psi
Flexural Strenght	66446 psi
Flexural Modulus	$2x10^6$ psi
Shear Modulus	$5x10^5$ psi
Barcol Hardness	39
Glass content	54 %
Density	1.6 g/cm^3

TABLE 3: CORE PROPERTIES

Shear Strenght	152 psi
Shear Modulus	4350 psi
Compression Strenght	181 psi
Density	90 Kg/m^3

FINITE ELEMENTS ANALYSIS

Due to the difficulty of obtaining an analytical solution to many engineering problems, involving complex geometry, properties of materials and boundary conditions, it becomes necessary to use numerical methods in order to obtain approximate solutions, more acceptable for these problems. In this matter, the Finite Elements Method is one of the most sophisticated methods of structural analysis.

As a tool for structural analysis, the programa of finite elements used was COSMOS/M 1.52 version, developped by Structural Research Analysis, Corp, Santa Monica, California and implanted in a microcomputer of the Naval Structure Laboratoy of COPPE/UFRJ. This program was chosen due to its great capacity of graphic generation an interactive use, allowing more flexibility and velocity inthe stage of design and optimization of the structure.

Taking in consideration the sandwich structure of the boat, each element of the hull is imagined as a shell element with five degrees of freedom, three of them concerning bending and two concerning the membrane element effect. This element allows us to take in consideration the single contribution of each laminate layer and considers the shear effect in the interior of the sandwich core. This element was used in the structural modeling of the hull,deck and bulkheads.

To simulate the bottom structure's contribution to the longitudinal resistence of the global model,the stiffeners were modeled using beam elements with 6 degrees of freedom.

Mass elements at the nodal points simulated the effect of concentrated loading, tanks, consumables, motors and equipment. The balance of the model was executed through the generation of vertical springs distributed in the bottom region, simulating the vessel's curve of pressures. The determination of the acting pressures [8] was done through the evaluation of vertical acelerations [9] and a hypothetic condition of sea, having LWL/12 as the significant wave height [10–11].

The finite elements model is presented in Figure 2.

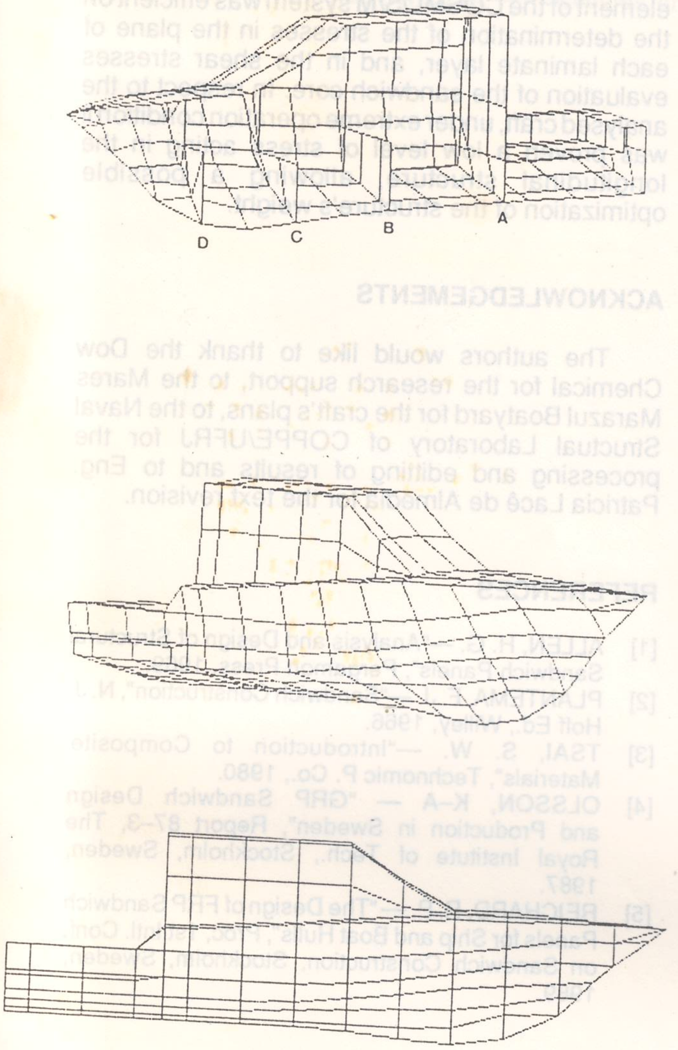


Figure 2

RESULTS

In the global analysis of the model with 1071 degrees of freedom we notice that the greatest tensions are located amidship craft's bottom, with average values of 6000 psi. The maximum values of tension are located near the C bulkhead. At deck, great tensions of compression are registered mainly in the plane aras of the bow, cockpit and cabine top, where deflections are close to L/150. Stresses and deflections at the longitudinal structure are relatively low, presenting safety factors for bending stresses above 8 and maximum deflections in the order of L/125. Shear stresses in the sandwich core presented safety factors above 3.5, at the most critical areas.

The finite elements deformed model is presented in Figure 3 and its stresses distribution in Figure 4. Stress distribution on bulkhead C is showed in Figure 5.

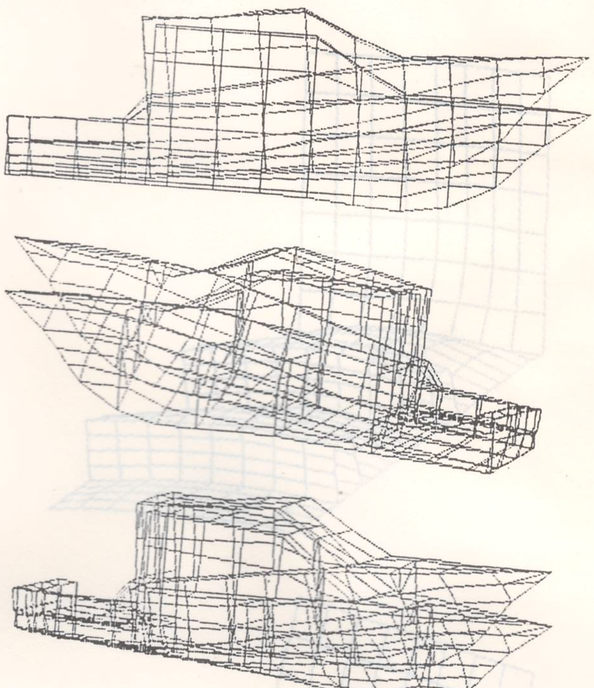


Figure 3

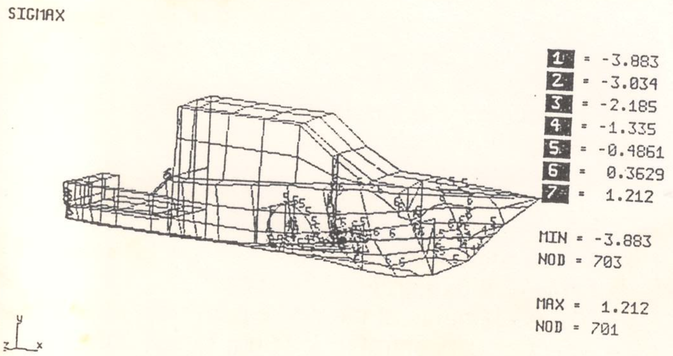


Figure 4

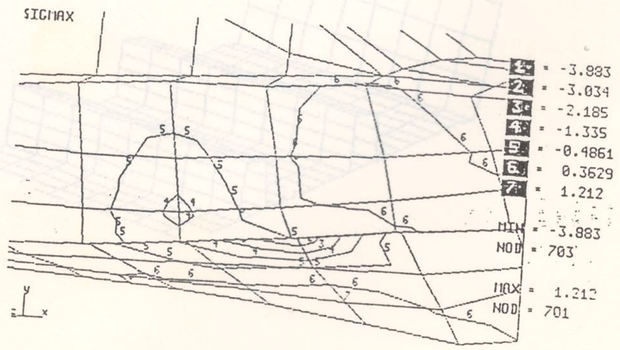
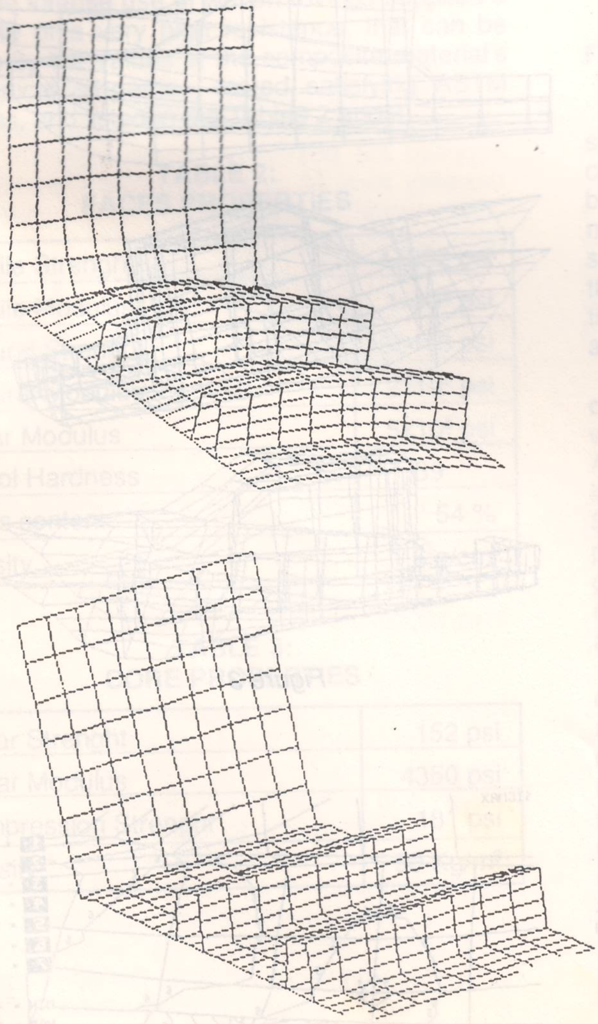


Figure 5

In the refined analysis of the longitudinal structure, in between the B and C bulkheads, the bottom stiffeners were discreated as shell elements of a single skin laminate. Using the conditions of simmetry, the same load of the global model was applied in this section. Stresses and deflections in the longitudinal structure were again lower, presenting the maximum deflection in the order of L/175 and safety factors above 10 for the membrane stresses. The most critcial region was the chine, the intersection of the bottom with the side of the boat, indicating by this analysis the necessity of a local stiffener, not considered in this model. However, when the construction of this vessel is verified, it can be observed that during its construction aditional layers of FRP tapes are included in this region.

The finite elements model of the analysed section and its deformed are shown in Figure 6.



CONCLUSIONS

Based on the performed analysis, the eficiency of the finite elements method for the determination of regions with stresses concentration has been verified, making it possible to identify, in the preliminary design stage, areas where an optimization of the lay-out and structure weight could be applied. The use of multilayer shell element of the COSMOS/M system was efficient on the determination of the stresses in the plane of each laminate layer, and in the shear stresses evaluation of the sandwich core. In respect to the analysed craft, under extreme operation condition it was proven a low level of stress acting in the longitudinal structure, allowing a possible optimization of the structure's weight.

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