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REVIEW

Decreasing of Ship Structure Mass by Active Counteraction to Bending Moment

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ABSTRACT

Pre-stressed structure and its application for civil engineering. Specificity of external loads of ships. Corresponded specificity of controllable pre-stressing. An example of pre-stressed structure and an decreasing estimation of its mass (about 10% of the full displacement). Possibility of wider application.

1. Introduction

Tday some civil engineers apply the pre-stressed structures for notable decreasing of structure mass. Such structure consists from two parts: usual structure from usual material and added details for high-tensile material, usually ropes, which pre-stress the main structure [1].

At the case the external loads are constant by sign; it means, the pre-stress is constant by sign too.

On the contrary, ship structure varies by value and sign at sea conditions; it means, the pre-stress must be variable one by value and sign.

An example of possible application of the pre-stressed structure (PSS) and its effect on structure mass is shown below for a super-fast vessel.

2. The Examined Object

A super-planing "wave-piercing" trimaran with air-born unloading (WPT) was proposed as a development of well-known "wave-piercing" catamarans to the zone of much bigger speeds (for example: [2-4]).

Figure 1 contains the exterior view of a WPT for 100 passengers, 24 cars, with design speed 100 knots, power 2 x 20 Mwt, range 600 nm at full speed.

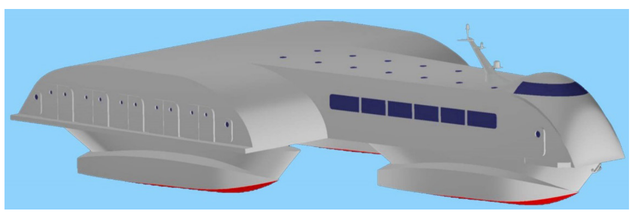

Figure 1. WPT for 100 passengers, 24 cars, speed 100 kn, up to Sea State 5 inclusive

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As all fast vessels, this type is very sensitive to the mass of the hull structure, especially – to the mass of above-water structure.

Besides, this type is not so deeply researched from the external loads point of view. This means that structural designing of the vessel must include some variations in the possible level of the external loads for the estimation of their influence on the structure mass.

3. External Loads

For all vessels, the main external loads are dynamic ones, i.e., the loads are defined by the vertical acceleration in waves. Such loads generate a general longitudinal bending moment and shear force.

In addition, transverse strength is depends from horizontal loads too, Figure 2.

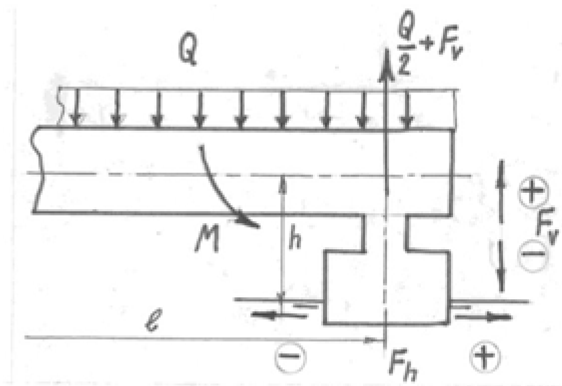

Figure 2. Transverse bending moment generation

The maximal transverse bending moment can be defined as:

$$M_{max}= Q*l/8 + F_V*l/2 + F_h*h$$

For example, an acceleration of 1.0 g and a speed of about 65 knots will be at Sea State 6. The second value, 2g, will be examined for a demonstration of the acceeration influence.The structure from light metal is supposed below.

4. Above-water Structure

The vessel's purpose defines the need for a big and free enough cargo deck, i.e., the above-water platform, which connects the hulls, is a "flat" enough structure. This leads to a problem in terms of structural design. The structure plan is shown in Figure 3. The above- water structure (wing + bow part) consists of longitudinal and transverse bulkheads and complex frames (each consists of lower and upper stringers with pillars between them); see below. Transverse rows of pillars at the wing form the car hangar. Car doors are at the end of each row (The doors must be air-tight for better flow around the above-water wing).

The external walls of the above-water platform's bow, where the passenger saloon is placed, are connected by complex longitudinal frames in the above-water wing; see Figure 4.

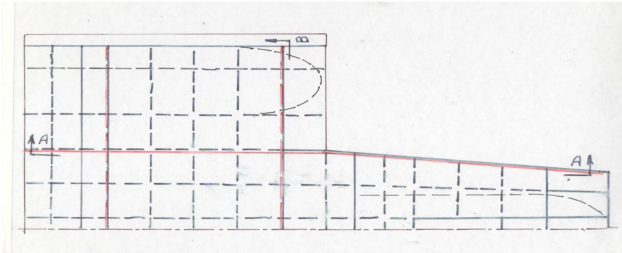

Figure 3. Plan of the above-water wing structure (red lines – added steel ropes)

The noted structure cuts are shown in Figure 4.

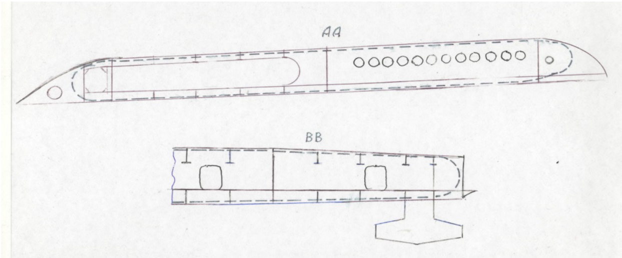

Figure 4. Longitudinal (AA) and transverse (BB) cuts of the wing structure (dotted lines – added steel ropes)

Usually, some well-known methods of decreasing mass are applied, such as external load minimization, structural optimization and use of the lightest material.

5. Method of Counter-acting

Variable (counter-acted) added moment: for any correlations between "bow up" and "bow down" loads, a there is a half of the value compensation, Figure 5.

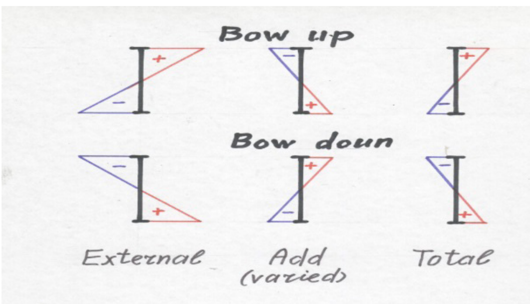

Figure 5. The amplitudes of normal stresses for the counteracted controlled moment

Evidently, the resulting stresses are equal to half of the initial stresses defined by the design loads.

This means that the structure parts, which are defined

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by the total moment, can have a smaller mass.

But the need for varied counteraction to the general bending moments means a need for a special system. The system must include some stress sensors, a control block and executing equipment, for example, small-sized winches. The characteristics of the system can be defined after a more exact selection of the needed degree of counteraction to the external bending moments.

A zero approximation of the values of the above-water wing structure mass is shown below.

6. Mass Estimation

Mass estimations are shown at the Table 1 for the following options: initial structure for design accelerstion 1 g; the same, 2 g; PSS for acceleration 2 g.

Table 1. Mass of the above-water structure options

Options	Design acceleration 1.0g, usual structure	Design acceleration 2.0g, usual structure	Design acceleration 2.0g, controlled moments
Transverse structure, t	58	71	66
Longitudinal structure, t	42	72	54
Total mass, t	100	143	120

Structure mass decreasing at 20 t means the possibility of growth of fuel supply at the same value, i.e. range growth at about 150 nm (up to 750 nm at full speed).

More exact definition of possible decreasing of structure mass can be carried out at the later stages of designing, when the full picture of external loads will be taken into account.

7. Conclusions

(1) Counteracting bending moment gives up to 20% drop of the above-water structure mass, i.e., about 10% drop of full displacement. It allows the bigger supply of fuel and range at full speed.

(2) The controlled counteraction to the general bending moments can be applied for any variable loaded structures, for example, for wings of aircraft.

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