A METHOD FOR COMPUTATION OF THE MAXIMUM PRINCIPAL STRESS FOR AN ELIPTICAL BULBOUS BOW DURING THE HYDRODYNAMIC IMPACT

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In această lucrare se face o analiză a tensiunilor maxime principale care se dezvoltă in timpul impactului hidrodinamic pentru mai multe tipuri de bulburi, pentru viteze de impact de la 1 la 10 m/s.

This works makes an analysis of the maximum principal stress which occur during a hydrodynamic impact for different types of bulbs withs impact speeds from 1 to 10 m/s.

Keywords: Bulbous bow, slamming, principal stress.

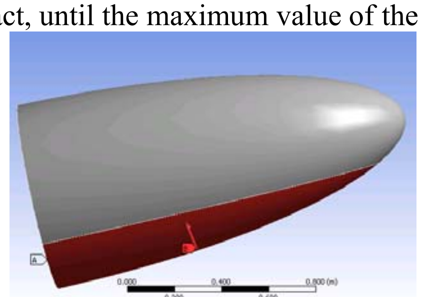
1. Introduction

In this paper, the authors make an analysis of the principal stress which occurs during a slamming phenomenon over a bulbous bow, for different types of bulbs.

2. Paper contents

We consider a semi elliptical bulb as a part of a bulbous bow, having the ratio between length and the base diameter equal to 2.

The bulb dives into the water keeping a constant speed in the first part of the impact, until the maximum value of the impact force is reached.



a)

b)

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Fig. 1

We start from the added mass formula:

$$m_a(t) = \frac{1}{2}\rho\pi a' b'^2 ; f_0(s) = \frac{1}{3}\rho\pi a b^2 \varsigma(t)^{\frac{3}{2}} f_0(s) \qquad (1)$$

where

$s = \frac{a'}{b'} \le 1$ and $f_0(s)$ is the added mass coefficient for an elliptic plate.

Unfortunately, there is no exact formula for the $f_0(s)$, but we know the limit values:

$f_0(0) = 1$ - for the point limit

and $f_0(1) = \frac{2}{\pi}$ - for the circle limit.

*a’ i*s the length of the surface defined by the intersection between the bulb and the water surface. $a' = a\sqrt{\varsigma(t)}$

b’ is the breadth of the same surface, measured in the constraining aria $b' = b\sqrt{\varsigma(t)}$

For a good result, one uses the following formula for computation of the $f_0(s)$ [1]:

$$f_0(s) = 1 - 0.094 \cdot s - 0.9140 \cdot s^2 + 0.9749 \cdot s^3 - 0.3302 \cdot s^4 \qquad (2)$$

The model has 1.6 meters in length and 0.8 meters for the base diameter.

After the computation, we reach that the maximum force F_{max} occurs when the body is submerged at the distance *d*=0.1673m, as we can see in Fig 1, a) and b).

We consider the force equally distributed over the wet surface, the vectors being normal to that, and the bulb being constrained at the aft end. (Fig 1.a)

Starting from the definition of the force, as time derivative of the impulse, taking in consideration that the speed is constant in the first period and the mass is the initial mass plus the added mass:

$$m = m_b + m_a \ , \qquad (3)$$

we can calculate the impact force:

$$F(t) = \frac{d}{dt} m(t) \cdot V = V \frac{d}{dt}(m_b + m_a(t)) \qquad (4)$$

where

V is the impact speed; *V=constant*

m_b is the bulb mass

Making the calculus, for *V*=1 $\left[\frac{m}{s}\right]$ we get the following results:

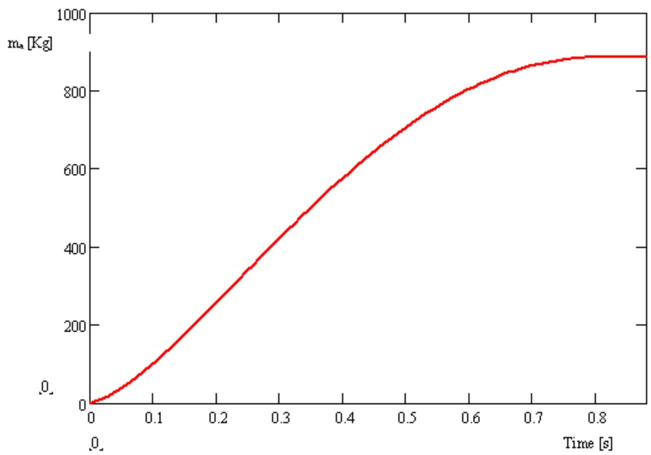

Diagram 1: The added mass variation

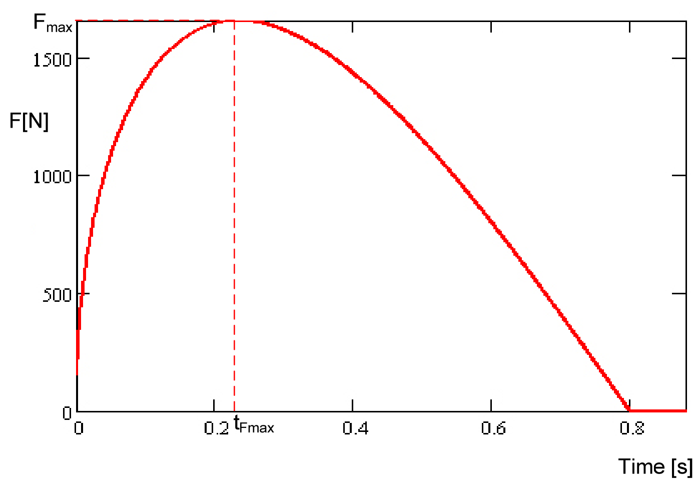

Diagram 2: The Force variation

From Diagram 2 we get the maximum force, F_{max}, and the time t_{Fmax} when F_{max} occurs.

The equation of motion for the bulb is:

$$Z = V \cdot t \tag{5}$$

where: t is time variable and Z is the depth reached by the bulb

Using the depth, we get the wetted surface at the intersection of the water plane with the bulb (Fig. 1a and 1b).

After the calculus, for speeds from 1 to 10 $[m/s]$ we get the following results:

Table 1

The values of *Fmax*, T_{Fmax}, and the depth

V	$Fmax$	t_{Fmax}	Depth
$[m/s]$	$[T_k]$	$[s]$	$[m]$
0	0	0	0
1	1.7015	0.23144	0.23144
2	6.8065	0.11704	0.23408
3	15.315	0.078027	0.234081
4	27.225	0.05786	0.23144
5	42.541	0.046816	0.23408
6	61.257	0.03872	0.23232
7	83.379	0.033314	0.233198
8	108.9	0.02893	0.23144
9	137.83	0.025813	0.232317
10	170.16	0.023232	0.23232

In the next step we design the finite element mesh, as shown in Fig 2:

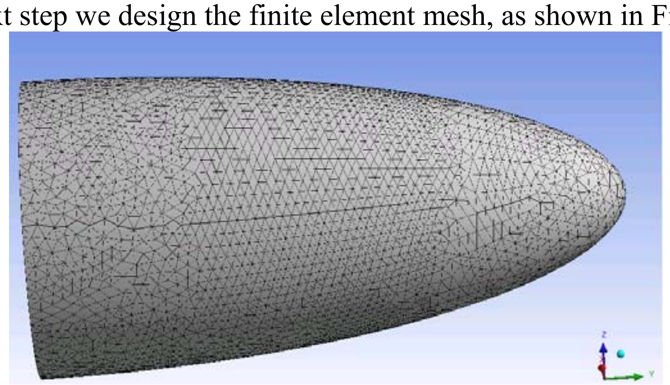

Fig 2

This structural idealization contains 10480 nodes and 42908 elements.

After the finite element analysis, the following distribution of the maximum principal stress is obatined (Fig 3).

The maximum value is reached at the upper region of the base, as shown in Fig 3.

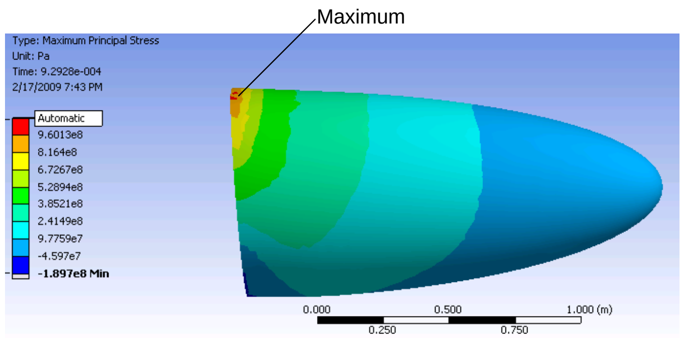

Fig 3

The variation of the maximum principal stress in time is shown in Fig 4.

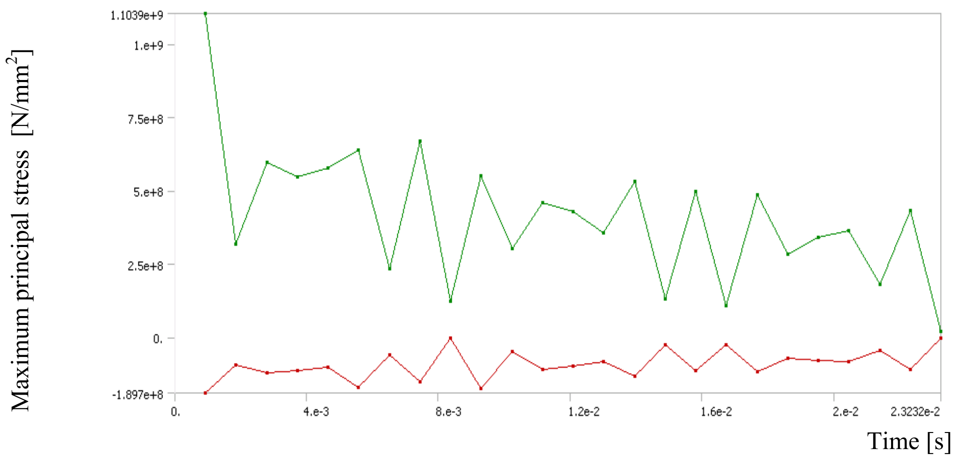

Fig 4.

Considering impact speeds in the range from 1 to 10 $[m/s]$, we obtain the values shown in Diagram 3.

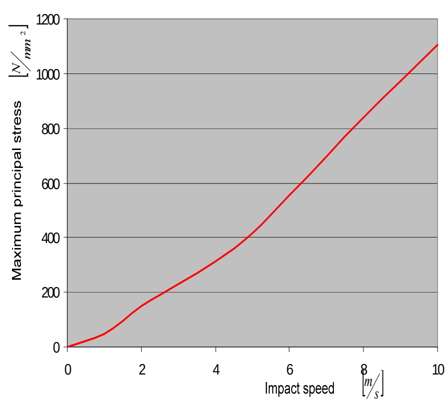

Diagram 3

3. Conclusions

This work makes a short analysis of the maximum principal stress using the finite element method, and having as a result a diagram usable by the interested persons, with the help of the similar theory.

The results are amendable, because in reality the bulbs don’t have a semi elliptical shape but a more complex shape, determined by hydrodynamic considerations.

REFERENCES

[1] *Katsuji Tanizawa, Zoshitaka Ogawa, Makiko Minami, Yasushira Yamada,* Water surface impact loads acting on bulbous bow of ships., proceedings of FEDSM03 2003 ASME/JSME Joint Fluids Engineering Conference July 6-10, 2003 Honolulu, Hawaii, USA

[2] *Leonard Domnişoru*, Metoda elementului finit în construcţiile navale (The Finite Element Method in Marine Constructions, in Romanian), Editura Tehnică, Bucureşti, 2001

[3] *G. Kumbetlian, G. Mândrulescu,* Rezistenţa materialelor – fundamente (Strength of Materials-Fundamentals, in Romanian), Editura Fundaţiei „Andrei Şaguna”, Constanţa 1998, 374 pagini, ISBN 973 – 9262 – 30 – 9

[4] *V G Szebehely, S. H. Brooks*, Hydrodynamics of slamming of ships NTMB Report 823, July 1952

[5] *O N Robinavitch, D M Rostovtsev, I V. Stepanov,* A survey of the Russian/ Soviet studies, results and data on hydrodynamic impact load estimation in marine (and non marine) design practice, St Petersburg State Marine Technical University, St Petersburg, Rusia, 1993

[6] *Iaffrati Alessandro; Korobkin Alexander A* Hydrodynamic loads during early stage of fat plate impact onto water surface, Physics of Fluids, Volume 20, Issue 8, pp 082104 – 082104 – 13 (2008)

[7] *Ole Andreas Hermundstad, Torgeir* Moan Numerical and experimental analysis of bow flare slamming on a Ro – Ro vessel in regular oblique waves, Journal of Marine Science and Technology, Japan, Volume 10, Number 3/ September 2005 ISSN 0948 – 4280

[8] *Yoshitaka Ogawa, Ryoju Matsunami, Makoto Arai* Effect of bow flare shape on water impact pressure International Journal of Offshore and Polar Engineering (ISSN 1053 - 5381), vol 16, No 2 June 2006, pp 112 - 117

[9] *** Software: Microsoft Office, Fluent