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STATE OF STRESS OF A HULL STRUCTURE RAMMED BY THE BOW OF ANOTHER VESSEL

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ABSTRACT

The study of structural strength of the hull structure is essential to determine the safety and integrity of the ship, in case of collision. The objective of this work is to study the impact loading of a ship bow on a strengthened plane structure, using FEA software ABAQUS.

Keywords: impact, FEA, Johnson-Cook model

1. INTRODUCTION

Nowadays, numerical analysis has a key role in determining the structural strength of the ship.

According to existing statistics for maritime accidents, made between 2011 and 2014, the collision between two ships and between a ship and shore have a significant percentage (Fig. 1).

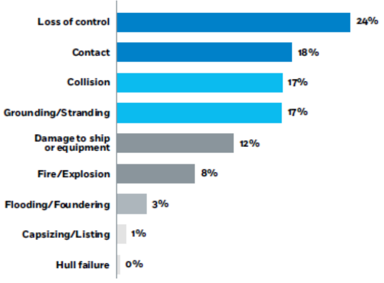


Fig. 1 The main causes of marine accidents

As a result, looking for new ways to ensure the integrity of the ship and save the lives of people on board have became research subjects.

2. THEORETICAL BACKGROUND

Because the experimental tests are expensive, theoretical models have been developed. They can facilitate the study of impact problems.

One of these theoretical methods is Johnson-Cook model [1], [2]. This is the most kown model for visco-plastic materials. It considers the stress rate effects on fracture and behavior model.

Parameters of this model can be easily found in free literature for different materials.

The equivalent stress is considered as a function of plastic strain rate and temperature. The relationship for the stress flow defined by Johnson and Cook is empirical. It is represented as:

$$\sigma_{flow} = \left[A + B\varepsilon^{n}\right] \cdot \left[1 + C \ln \dot{\varepsilon}^{*}\right] \cdot \left[1 - \left(T^{*}\right)^{m}\right]$$

where A, B, C, n and m are the material parameters measured at or below the transition temperature T^*, ε is the plastic strain, $\dot{\varepsilon}^* = \dot{\varepsilon}/\dot{\varepsilon}_0$ is the plastic strain rate (dimensionless) for $\dot{\varepsilon}_0 = 1s^{-1}$, and the temperature T^* is defined as (dimensionless):

$$T^* = \frac{T - T_{room}}{T_{melt} - T_{room}}.$$

This model is fracturing and considers load history. The occurrence and crack propagation depends on the stess rate, temperature and pressure.

The Johnson - Cook model is also an instantaneous failure model. It means that no strength or stiffness remains after erosion (failure) of an element, at least in stress. (Maxime Jutras, 2008 [3])

For strain at fracture the general expression is given by:

$$\varepsilon^f = \left[D_1 + D_2 \exp D_2\sigma^*\right]\cdot \\ \left[1 + D_4 \ln \dot{\varepsilon}^*\right]\cdot\left[1 + D_5 T^*\right]$$

where $D_i = \overline{1,5}$ is represented by constants of the damage model D_1, D_2, D_3 are constants for the triaxial state of stress, D_4 is the strain parameter, D_5 the temperature parameter for constant values of the variables ($\sigma^*, \dot{\varepsilon}^*$ and T^*) and for $\sigma^* \leq 1,5$.

The dimensionless pressure/stress ratio is a measure of triaxiality of the stress state and is defined as:

$$\sigma^* = \frac{\sigma_H}{\sigma_{eQ}}$$

where σ_H is the hydrostatic stress,

$\sigma_H = \sqrt{\frac{2}{3}\sigma_{ij}^D \sigma_{ij}^D}$ the von Mises equivalent stress. (Maxime Jutras, 2008 [3]).

3. NUMERICAL SIMULATION

The main objective of this analysis is to study the impact loading of an offshore patrol vessel bow on a strengthened plane structure, using FEA (Finite Element Analysis) software Abaqus (explicit dynamic modulus). It was manufactured by the company Dassault Systems.

It is necessary to define an element deletion criterion. In this way, the ship bow will pass through the plane structure.

It will be considered that the plane structure is the side shell of one vessel midship. It is strengthened with steel flat bar profiles.

Numerical simulations will include the following cases:

a) the impact between the bow and the side shell, strengthened with longitudinal and transversal profiles, at the minimum patrol speed of12 Kn;

b) the impact between the bow and the side shell, strengthened with longitudinal and transversal profiles, at the minimum patrol speed of 20 Kn.

The main characteristics are presented in Table 1.

Table 1. Principal characteristics.

Plate			Profiles	Bow	
Length [mm]	Breadth [mm]	Thickness [mm]	Type [mm] x [mm]	Length [mm]	Diameter [mm]
12000	8000	10	FB 180x10 FB 270x10	4550	6000

The 3D-CAD model of ship bow is developed in AutoCAD 2016 and then it was imported in Abaqus. In this way, the actual shape of the bow is preserved. On the other way, the plane structure is generated in Abaqus because it has a simple geometry. (Fig. 2).

For plane structure, there were used hexahedral type elements and for bow structure, tetrahedral type elements, as it is shown in Figure 2a, 2b.

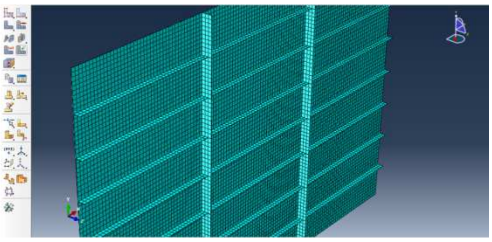


Fig. 2a Plane structure mesh

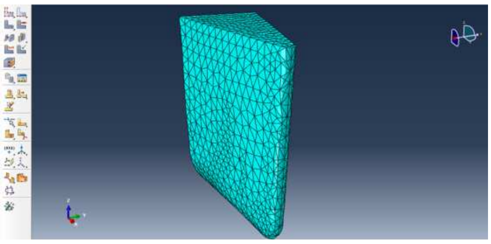


Fig.2b Bow mesh

The 3D-FEM plane structure has naval steel grade AISI 4340 and the projectile is considered to be a linear material with the modulus (E), Poisson's ratio (ν) and density (ρ) of steel (Table 2a).

Table 2a Material characteristics

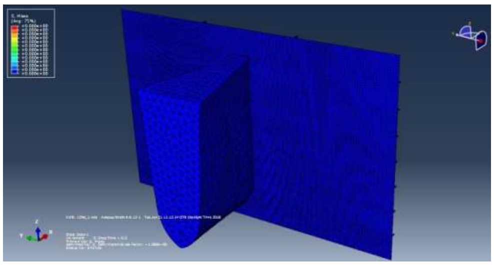
	Steel (plate)	**Steel (bow)**
E (MPa)	205000	205000
ν	0.3	0.3
ρ (t/mm^3)	7.85E-9	2.79E-8

Table 2b Johnson-Cook parameters

	Steel (plate)	**Steel (bow)**
A (MPa)	792	792
B (MPa)	510	510
n	0.26	0.26
m	1.03	1.03
D_1	0.05	-
D_2	3.44	-
D_3	-2.12	-
D_4	0.002	-
D_5	0.61	-

The plane structure is fixed at the edges in all degrees of freedom. The bow has an initial velocity of 12 Kn and, for second case, 20 Kn.

The results for case a) are shown in the following images:



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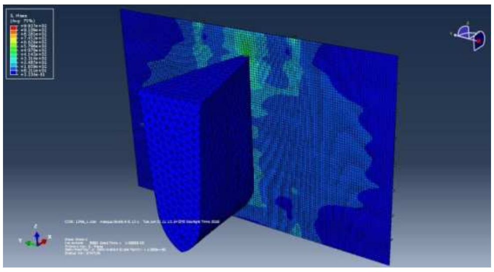

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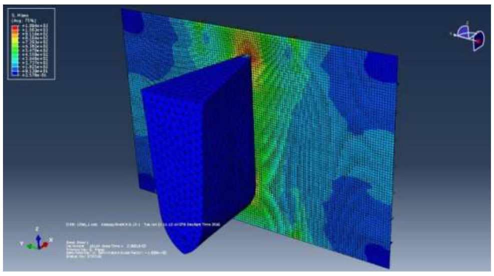

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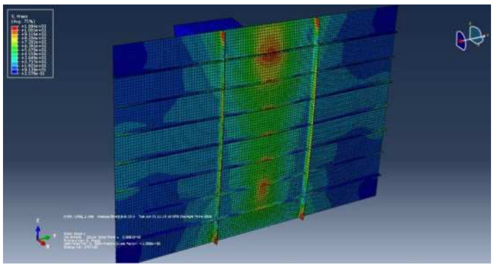

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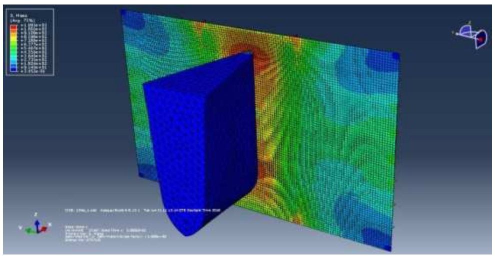

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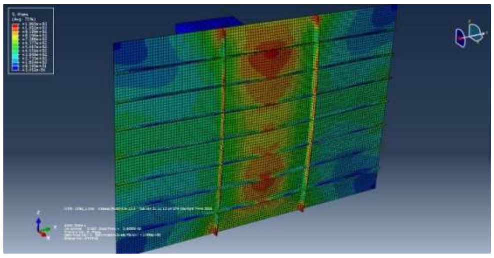
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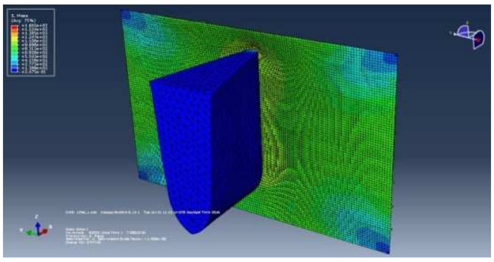
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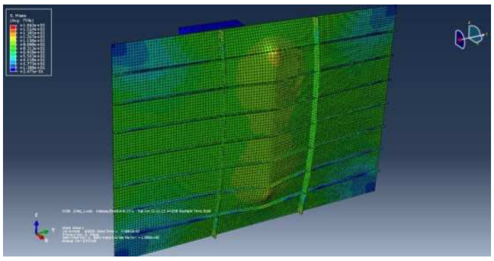
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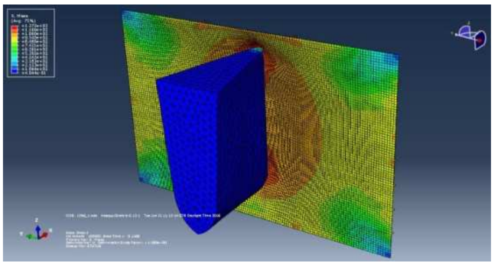
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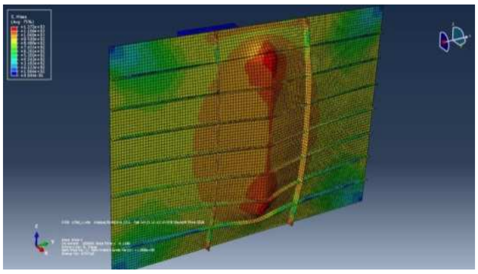
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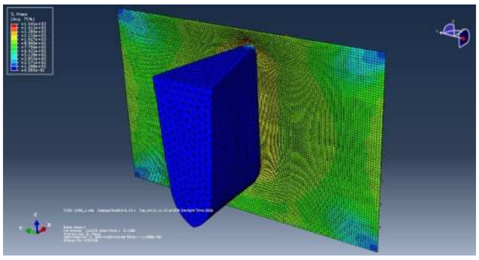
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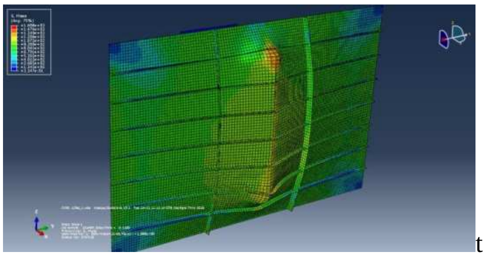
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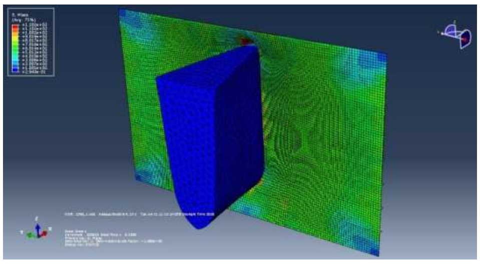
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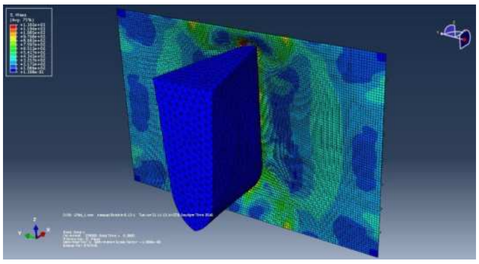
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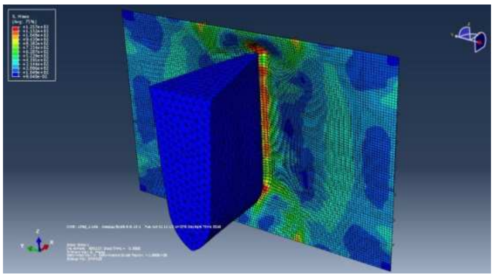
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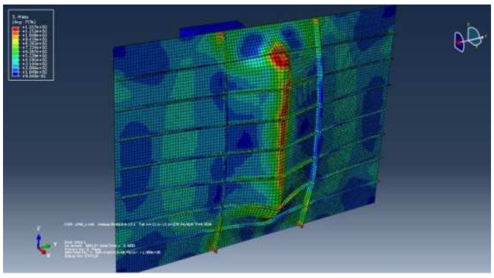


t9 (back)

Fig. 3 Case a) results

In Figure 4a and 4b are plotted the kinetic energy (presented as a result of the motion of the mass) and the strain energy (presented as a result of the displacement of the structure). They are represented as functions of time for the entire model considered.

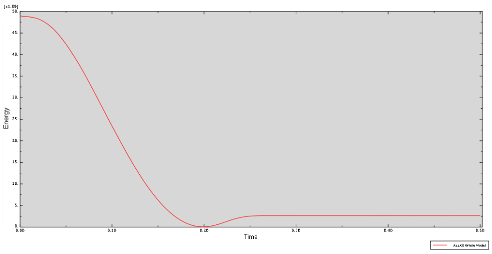


Fig. 4a Kinetic energy (case a)

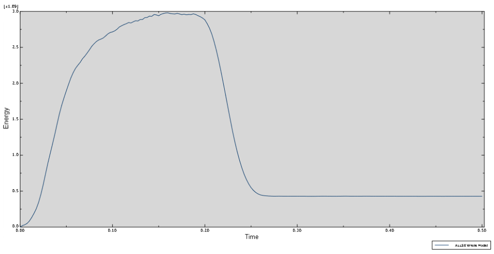
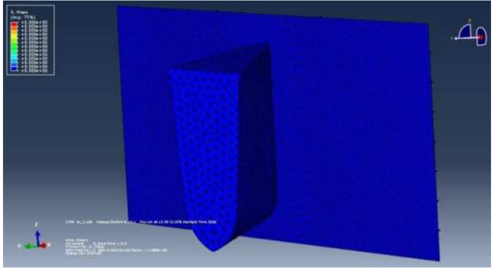


Fig. 4b Strain energy (case a)

The results for case b) are shown in the following images:



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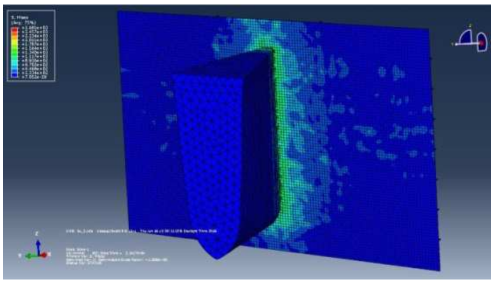

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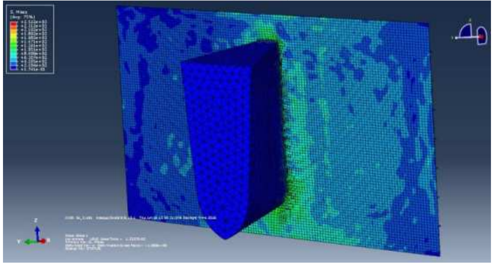

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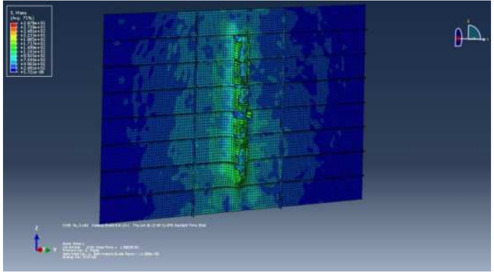
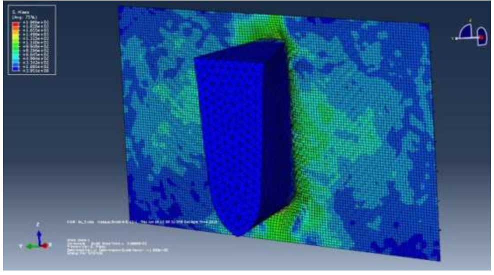


t2 (back)



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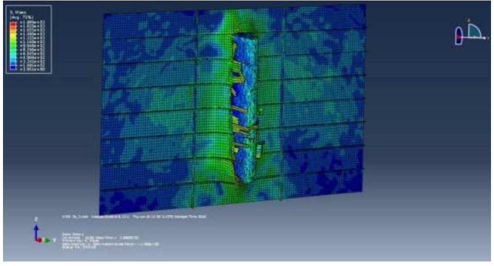
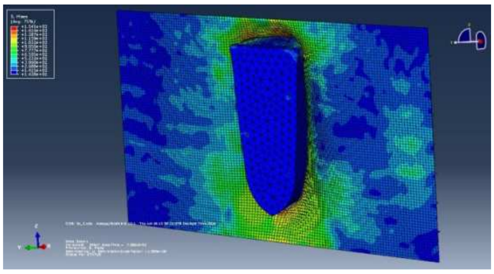


t3 (back)



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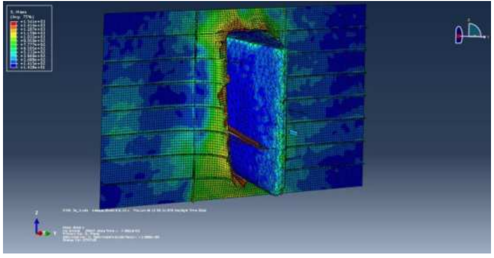

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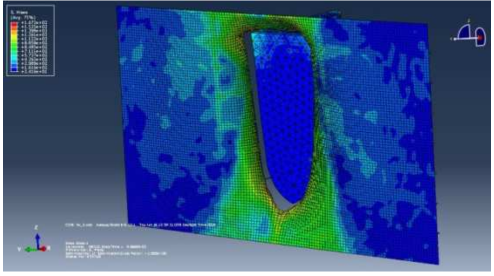

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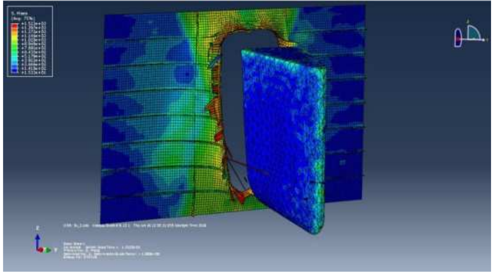

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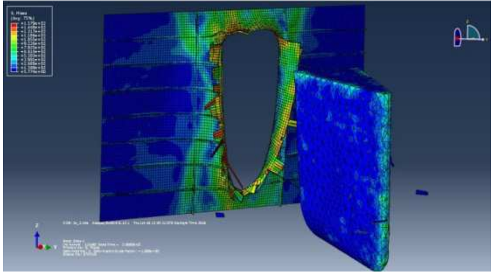

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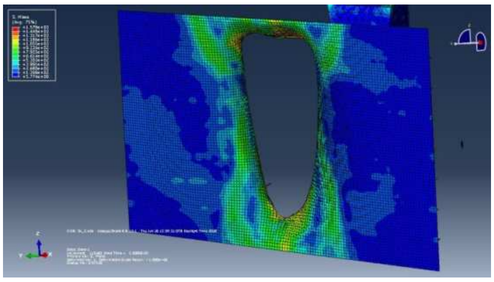

t6 (back)

Fig. 5 Case b) results

Also, for case b), in Figure 6a and 6b are plotted the kinetic energy and the strain energy.

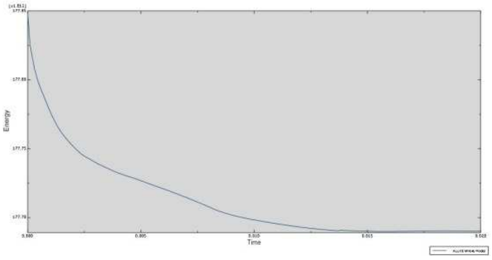

Fig. 6a Kinetic energy (case b)

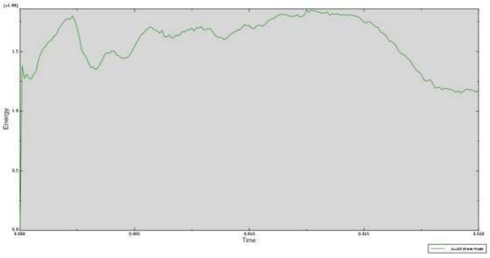

Fig. 6b Strain energy (case b)

3. CONCLUSIONS

From these results, it can be seen that the kinetic energy (Fig. 4a, 6a) of impacting bow drops and some of it turns into strain energy. Due to this decrease, it can be observed the increase of strain energy (Fig. 4b, 6b).

Also, when impact speed is 12 Nd, we can see that deformations occurred are likely to be plastic and a part of the vessel energy is converted into elastic energy of deformation so that it is moved in the opposite direction of initial displacement.

In the case of 20 Nd, it can be observed that the bow runs through the side shell. In this situation the plane structure is destroyed.

This work represents the beginning of the research process whose purpose is to establish the methodologies for verifying the maritime structures for impact cases and beyond.

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