ANALYSIS OF THE IMPACT RESISTANCE OF A FLOATING WORKSHOP

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Abstract: *For decades, Finite element analysis (FEA) has served as a tool for solving various problems in fields, for example: engineering, naval field, medicine, etc. Once the software using this numerical method has evolved, the diversity of problems that can be solved has automatically increased. This article demonstrates that complex analyzes can be performed using the finite element method, thus avoiding physical tests that involve very high costs. In this case, the impact of a steel floating workshop with a rigid surface of concrete it's analyzed. It is known that it detaches from the crane during transport and falls freely from a height of 10 m.*
Keywords: *Finite element analysis, floating workshop, impact, free fall, naval field.*

1. INTRODUCTION

Drop testing is a process generally used to evaluate the fragility of a product, whether packed or not, and to simulate any shocks that may occur when handling manually or mechanically. Products are exposed to tests similar to those they will experience during distribution or after they reach an end user. This type of test is an important indicator of quality and durability [1].
Why drop testing or impact testing is important to do?

- to help validate the design of a product;
- to define the impact tolerance of the products;
- to reproduce shocks that may occur during transportation, installation or use of a product;
- for accelerated lifetime testing;
- to identify any damage to a product;
- to evaluate the ability of a package to protect the product by understanding the depreciation capacity of the materials used.

One of the most important advantages of using this method is that we can simulate real-world impacts on the finished components or products and collect detailed technical information about how products perform under collision.

1.1. Drop testing in naval field

As in many other cases, the drop test is also used in the naval field. But in this situation, the simulations are done on the computer, due to the very high production costs. Thus, software based on the finite element method is used which allows the testing of higher complexity, that provides results close to the real ones.
The analyzed structure presented in this paper is a floating workshop for shipyard activity which was designed and built at Galați through the *"UGAL INVENT"* event from 7-9 October 2015. This workshop was built to be equipped with tools and machines used for small operations such as welding, grinding, drilling, bending and used to repair bigger ships. An important feature of the floating workshop is its mass, having possibility to be placed in various places in shipyard just by lifting with a crane [2].

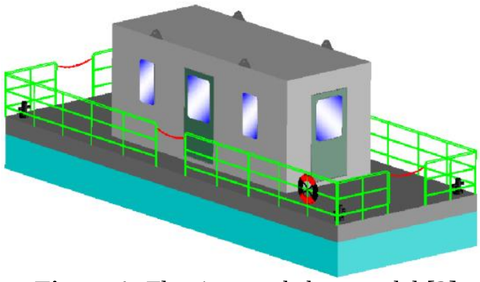

Figure 1: Floating workshop model [2]

1.2. 3D CAD model of the floating workshop

The floating workshop geometry was made using the ANSYS Workbench Geometry module. The entire 3D CAD model has three components: the container-workshop that is placed on the pontoon, the pontoon and the concrete mass.

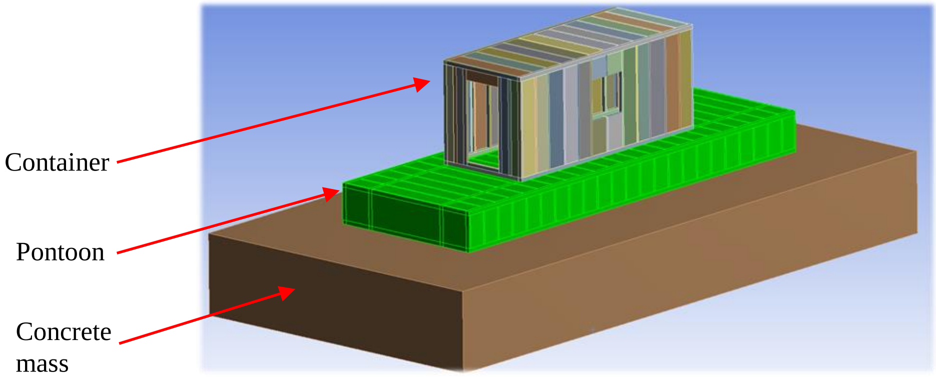

Figure 2: The geometry of the floating workshop [5]

The container and the pontoon were created with surface type elements and the concrete mass with volume type elements using some of the software drawing commands, for instance: Sketch, Extrude, Translate, Pattern, Rotate.

Table 1: Overall dimensions [5]

	Length [m]	Width [m]	Height [m]
Container	6.058	2.438	2.548
Pontoon	11.500	3.982	1.000
Concrete mass	16.000	8.000	2.000

2. MATERIALS AND METHODS

In order to perform this analysis, the Explicit Dynamics module from ANSYS Workbench was used to address nonlinear problems. This module is usually used for simulations involving: shock wave propagation, large deformations and strains, non-linear material behavior, complex contact and fragmentation.

2.1. Explicit Dynamics procedure

Since it is a mathematical method, there is a set of steps that are performed for each element separately, to obtain the solution. It is known that for a linear analysis, nodal displacements, strain and stress are determined but for a non-linear analysis, besides this, the nodal accelerations are determined also. All the calculations steps that are performed by the software are listed below [3]:

- Solution starts with a discretized model with finite elements, which is assigned the type of material, loads, constraints and initial conditions;
- Integration in time establishes the motion in the nodes of the elements;
- Motion of the nodes produces deformation of the elements;
- The deformation of the elements produces changes in the volume and density of the material in each element;
- Deformation rate is used to derive strain rates;
- Constitutive laws derive resultant stresses from strain rates;
- Stresses are transformed back into intern nodal forces;
- External nodal forces are determined from boundary conditions, loads and contact;
- The nodal accelerations are produced by dividing the total nodal forces with the nodal mass;
- Nodal accelerations are integrated explicitly in time to produce new nodal velocities;
- Nodal velocities are integrated explicitly in time to produce new nodal positions;
- The solution process (Cycle) is repeated until the calculation end time is reached.

2.2. Stability Time Step in Explicit Dynamics

The time steps that are used for explicit time integration is usually much smaller than those used for implicit time integration. There is a condition for the time step in Explicit time integration and implies that the time step be limited such that a disturbance (stress wave) cannot travel further than the smallest characteristic element dimension in the mesh, in a single time step [3].

$$\Delta t \le f \cdot \left[\frac{h}{c}\right]_{min} \tag{1}$$

where ***Δt*** is the time increment, ***f*** is the stability time step factor (= 0.9 by default), ***h*** is the characteristic dimension of an element and ***c*** is the local material sound speed in an element.

2.3. Materials

In general, materials have a complex response to dynamic loading, particularly when the loading is sudden, powerful and damaging. The materials available for Explicit Dynamics simulations facilitate the modeling of a wide range of materials and material behaviors. In this case, a non-linear behavior material from the software library was used for both the floating workshop and the concrete mass. In order to standardize the steel chosen from the program library, the European design code [4] was consulted and the S275 Steel was selected, having the following material properties:

Table 2: Material properties [4]

Yield Strength [MPa]	Young's modulus [Pa]	Poisson's ratio
275	$2.1 \cdot 10^{11}$	0.3

3. RESULTS AND DISCUSSION

It is known that the floating workshop it detaches from the crane and falls freely from a height of 10 meters. In simulations, this distance will be eliminated to reduce the computation time. Thus, the structure will be assigned an initial speed calculated with the following formula:

- the friction with air is neglected, and at ***h*** height the structure has maximum potential energy and zero kinetic energy.

$$E_p = mgh \tag{2}$$

where ***m*** is the floating workshop's mass, ***g*** is gravitational acceleration and ***h*** is the height.

- at the moment of collision with the concrete mass, the floating workshop has the maximum velocity (therefore maximum kinetic energy) and zero potential energy.

$$E_c = \frac{mv^2}{2} \tag{3}$$

where ***v*** is the velocity of the floating workshop.

- using the energy conservation theorem results:

$$v = \sqrt{2gh} \tag{4}$$

$$v = \sqrt{2 \cdot 9.81 \cdot 10} = 14\, m/s \tag{5}$$

To obtain more information about the behavior of the floating workshop at the time of the collision with the concrete mass, several tests were performed. It started from less critical cases to the worst case possible. Each case had a different solving duration and even a different collision time (End time) depending on the position of the structure at the time of impact. In each individual case, the following results were attended:

- Displacements;
- Equivalent stress (von-Mises);
- Equivalent plastic strain;
- Kinetic energy;
- Contact energy.

3.1. First case

For the first simulations the floating workshop falls in a direction parallel to the concrete mass and affects all its lower surface.

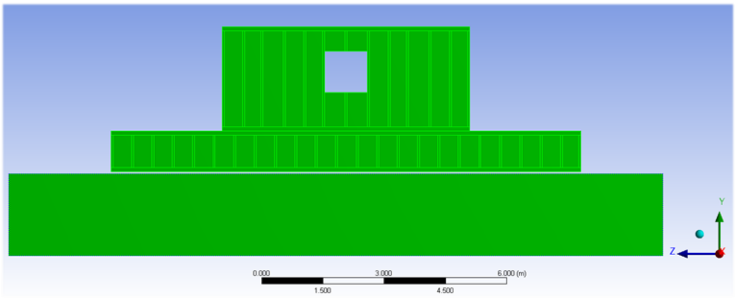

Figure 3: Orientation of the floating workshop at the time of impact [5]

The collision time (End time) was 0.04 s, enough that the kinetic energy of the pontoon reaches a value close to zero. The solving duration was about 2.5 hours and ran on a device with a i7-8550 processor with 4 cores. After the simulation the results were visualized and information about the Equivalent Plastic Strain and Plastic Work Energy variation were taken over.

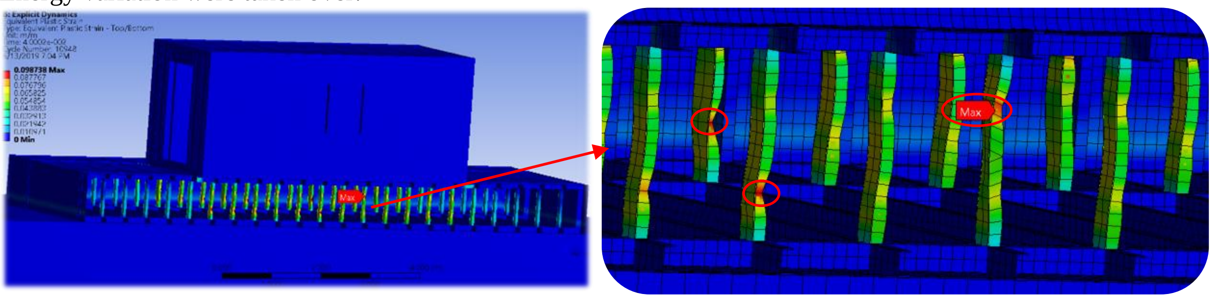

Figure 4: The graphic representation of the Equivalent Plastic Strain [5]

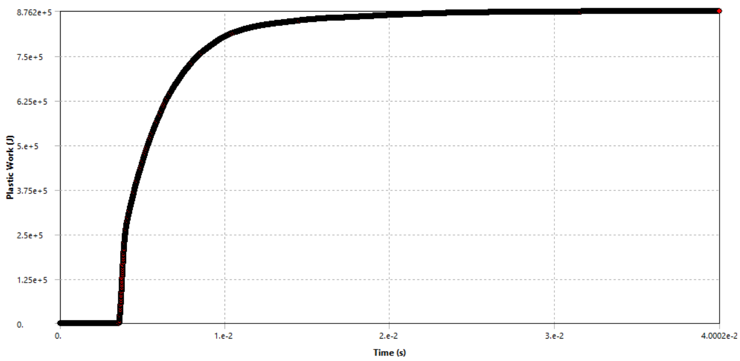

Figure 5: Variation in time of the Plastic Work Energy [5]

3.2. Second case

This time the floating workshop spins in the air and hits the concrete mass with the edge of the width from an angle of 12 degrees.

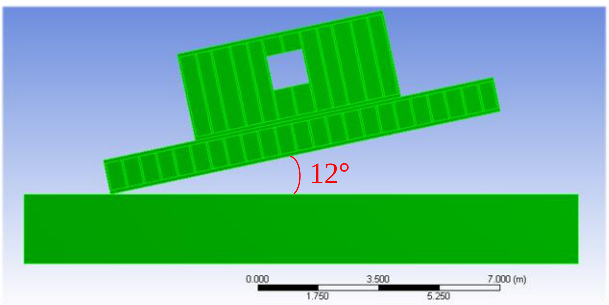

Figure 6: Orientation of the floating workshop at the time of impact [5]

The collision time (End time) in this case was 0.15 s, during which time the floating workshop came in contact with the concrete mass on its entire lower surface and began to move in the opposite direction. The solving duration was about 20 hours and ran on a device with a i5-520M processor with 2 cores, which shows that the performance of the device on which the simulation takes place influences the duration of the solution.

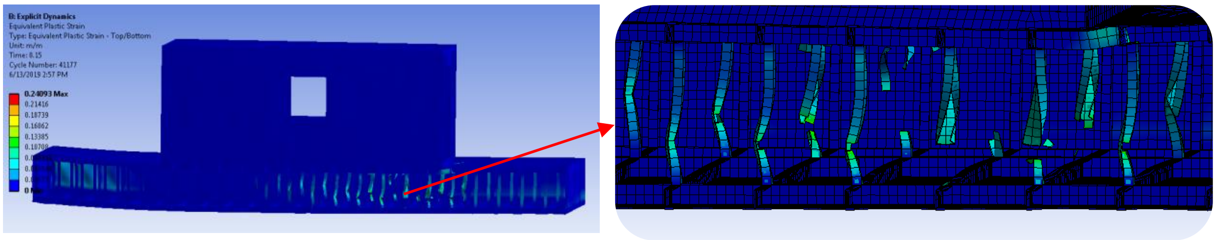

Figure 7: The graphic representation of the Equivalent Plastic Strain [5]

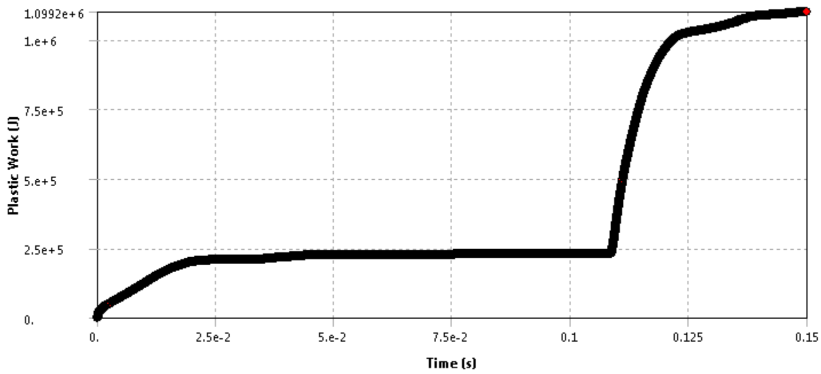

Figure 8: Variation in time of the Plastic Work Energy [5]

3.3. Third case

The last case studied was considered to be the most critical. The floating workshop hits the concrete mass at an angle of 15 degrees to the Z axis and 10 degrees to the X axis.

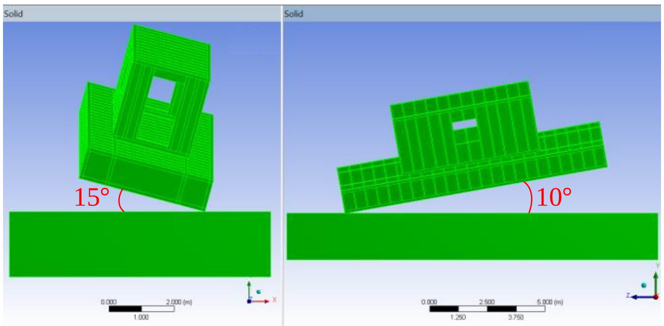

Figure 9: Orientation of the floating workshop at the time of impact [5]

The collision time (End time) was 0.2 s and as in the previous case the simulation ran until the floating workshop began to move in the opposite direction. The solving duration was about 10 hours and performed on the same device as the first case.

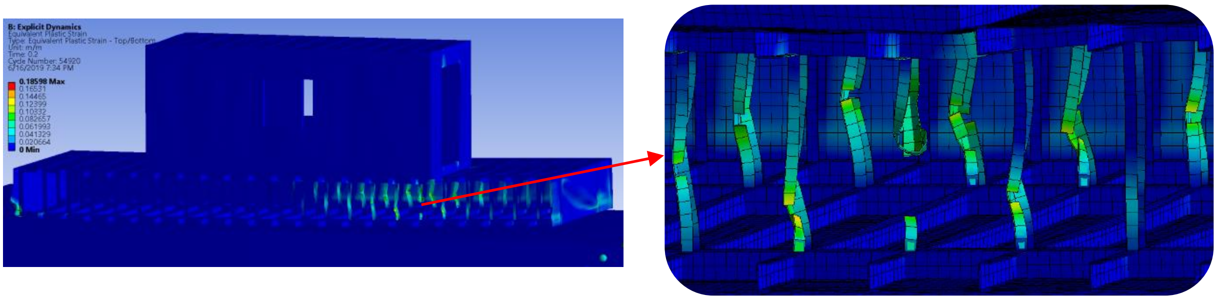

Figure 10: The graphic representation of the Equivalent Plastic Strain [5]

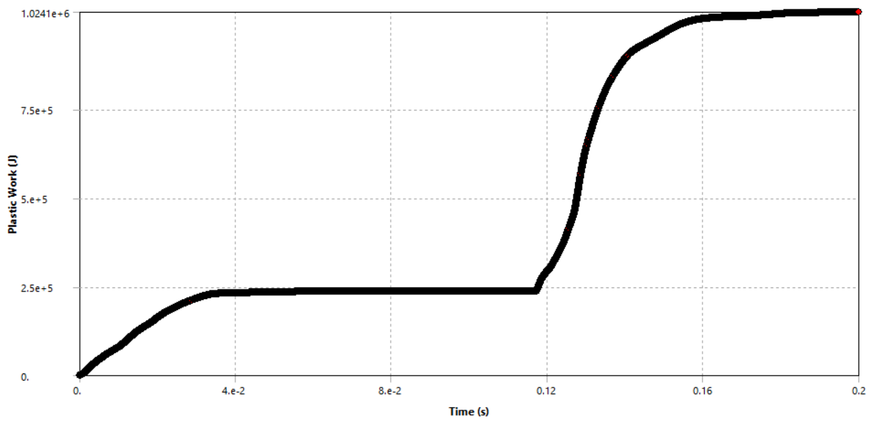

Figure 11: Variation in time of the Plastic Work Energy [5]

4. CONCLUSION

These simulations were performed to see the behavior of the floating workshop on the impact with the concrete surface. The values that were mainly acquired were the Equivalent stresses (von-Mises) and Equivalent Plastic Strain. It is noticed that in all three cases the Equivalent stresses exceed the Yield Strength value of the chosen material, which leads to the occurrence of Plastic Strain.

Table 3: Max values of Equivalent stresses (von-Mises) for each case [5]

Simulation	Collision time (End time) [s]	Max Equivalent stresses values (von-Mises) [MPa]	Material Yield Strength [MPa]
First	0.04	381	275
Second	0.15	434	
Third	0.2	420	

It was assumed that the third case will be the most critical considering the orientation of the floating workshop at time of impact but the highest values for the Plastic Work Energy and Equivalent Plastic Strain were recorded in the second case.

Table 4: Highest values for the Plastic Work Energy and Equivalent Plastic Strain [5]

Simulation	Max Plastic Work Energy values [J]	Max Plastic Strain values [m/m]
First	$8.76 \cdot 10^5$	0.098
Second	$10.9 \cdot 10^5$	0.24
Third	$10.2 \cdot 10^5$	0.18

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