A Software For Design And Management Of Lifting Operations For Shipbuilding And Offshore Construction

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Abstract. *World´s industry of shipbuilding and offshore construction experience a strong growing, demanding even faster, more modular, heavier fabrication and construction. For this reason, lifting operations are becoming increasingly important for the effectiveness of the projects. Moreover, deadlines are getting shorter, constructions are becoming even more simultaneous and the lack of space hinders the lifting operations. Therefore, the design and management of lifting operations are critical tasks that must be supported by a modern and integrated computer software.*

This paper describes the structure of the Software developed by the Author and main features about designing and management of lifting operations, such as: slings and rigging hardware design and detailing, equipment handling, configuration and capacities, collision detection, proximity alarm, inventory and inspection of slings and accessories and others.

The loads can be of any type, shape or weight and possible lifting equipment may be of any type: mobile cranes, gantry cranes, tower and pedestal cranes, modular trailers and any other type created by the user.

Finally, it presents the features for production of engineering drawings and 3D video simulations of the lifting operations.

Keywords*: shipbuilding; offshore construction; lifting, heavy lifting, cranes.*

1. INTRODUCTION

World´s industry of shipbuilding and offshore construction experience a strong growing, demanding even faster, more modular, heavier fabrication and construction. For this reason, lifting operations are becoming increasingly important for the effectiveness of the projects. Moreover, deadlines are getting shorter, constructions are becoming even more simultaneous and the lack of space hinders the lifting operations and construction.

Lifting operations are often risky operations, especially in the environment of shipbuilding and offshore construction, where the load weight is far greater than in most other industries. Therefore, design, planning, management, inspection and testing activities are essential to perform the lifting operations, seeking not only the safety and preservation of facilities, but also the success of the assembly of the blocks (Roncetti, 2011).

In addition, there is the complexity of the activity itself, involving many physical and geometrical interference, equipment availability and obstructions in the areas of manufacturing and assembly, among others, which may compromise cost and time if those are not considered.

Therefore, automated designing and management tools for heavy lifting operations are required to improve effectiveness and competitiveness of a shipyard.

The Author developed a Software to perform the design and management of the lifting operations using a virtual reality environment and the state of the art in heavy lifting techniques. The aim of this paper is to describe the main features of the system.

2. OBJECTIVES OF THE SOFTWARE

The overall objective of the Software is to create an integrated and modular platform for the development of design, planning, management, inspection and testing activities for lifting operations, focusing on shipbuilding and offshore construction, through multi-interface environments, including virtual reality, technical drawings, reports and videos, all of them in real time.

The Software can also be used for training, teaching and inventory for lifting equipment and accessories.

3. MAIN FEATURES

3.1. General

The Software has a main module called "Control Panel", responsible for overall control of operations and linking of modules. It is also responsible for access to equipment records, records of operations and databases.

When operating, the user choose the equipment to be used, the load to be moved or lifted and the necessary settings, allowing simultaneous operation using as many devices needed. It also allows parallel operation, that is, with multiple independent loads and equipment, and the maximum number of elements involved depends only on the computing capacity of the hardware used, since there is no limit for records and use of equipment and loads.

3.2. Scenarios

The Scenarios are the virtual representation of the shipyard areas, that is, the physical space where lifting and handling operations will be carried out. They are modeled in 3D by the user, through the CAD platform, using a level of detail appropriate to the type of operation to be designed and representing the various fixed structures that compose the shipyard: buildings, shops, dry docks, floating docks, wharves, piers, pre-construction areas, storage areas and more (Gaythwaite, 2004). Each scenario forms a single file that is shared among all those who are designing and planning in it, hence, when a scenario is upgraded, the update is immediately reflected in all instances.

The files containing the Scenarios can be independent and it is possible to hierarchically group them to have sets of Scenarios, with the advantage to be able to design and plan on reduced Scenarios, when the area of operation is restricted, speeding computational processing. On the other hand, the user can join multiple Scenarios to plan for example, the transportation/lifting of a complex block from shop to dry dock.

It's also made a multilayer structure to unite the works, equipment and accessories, maintaining the independence of the files. A possible hierarchy and multilayer structure is illustrated in Fig. 1.

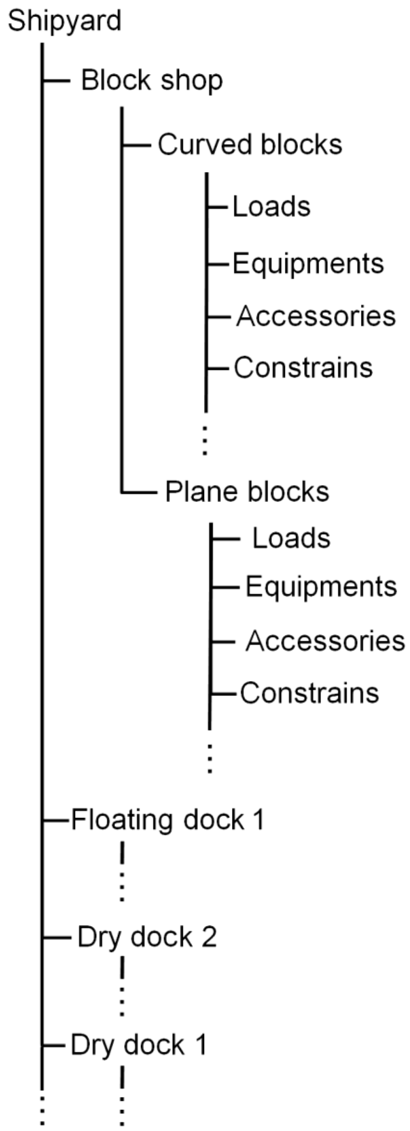

Figure 1. Structure of Scenarios.

The files of the Scenarios can be used as records of the facility's shipyard, using an information system 4D.

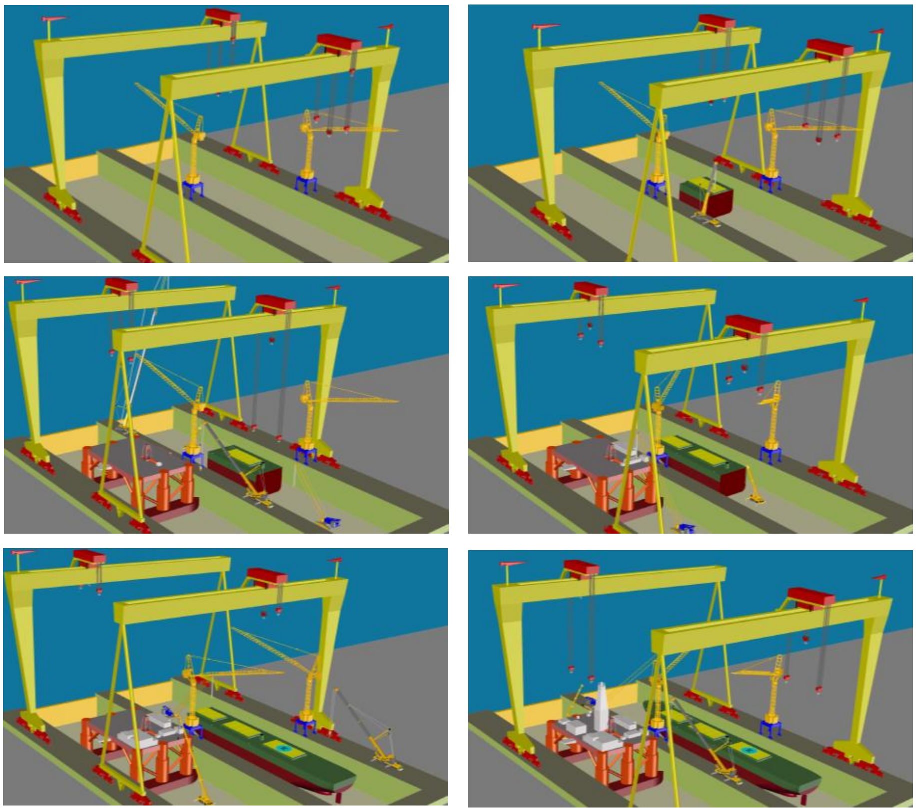

Figure 2. Automatic Scenario generation varying in time, according to the date of planning or management.

In the selected Scenario or set of Scenarios, according to the date of operation, “Prohibited Areas”, “Prohibited Volumes”, “Interdicted Areas” and “Interdicted Volumes” are displayed on multi-layers (Fig. 3). A "Prohibited Area" defines an area on the horizontal plane where load, equipment or accessories cannot be placed, although they can operate over it. A “Forbidden Volume” defines a volume of any geometry in which nothing can be done. Prohibited Volumes and Areas are not open to negotiation while the status of Interdicted Volumes and Areas can be reversed through the “Manager of Negotiations”.

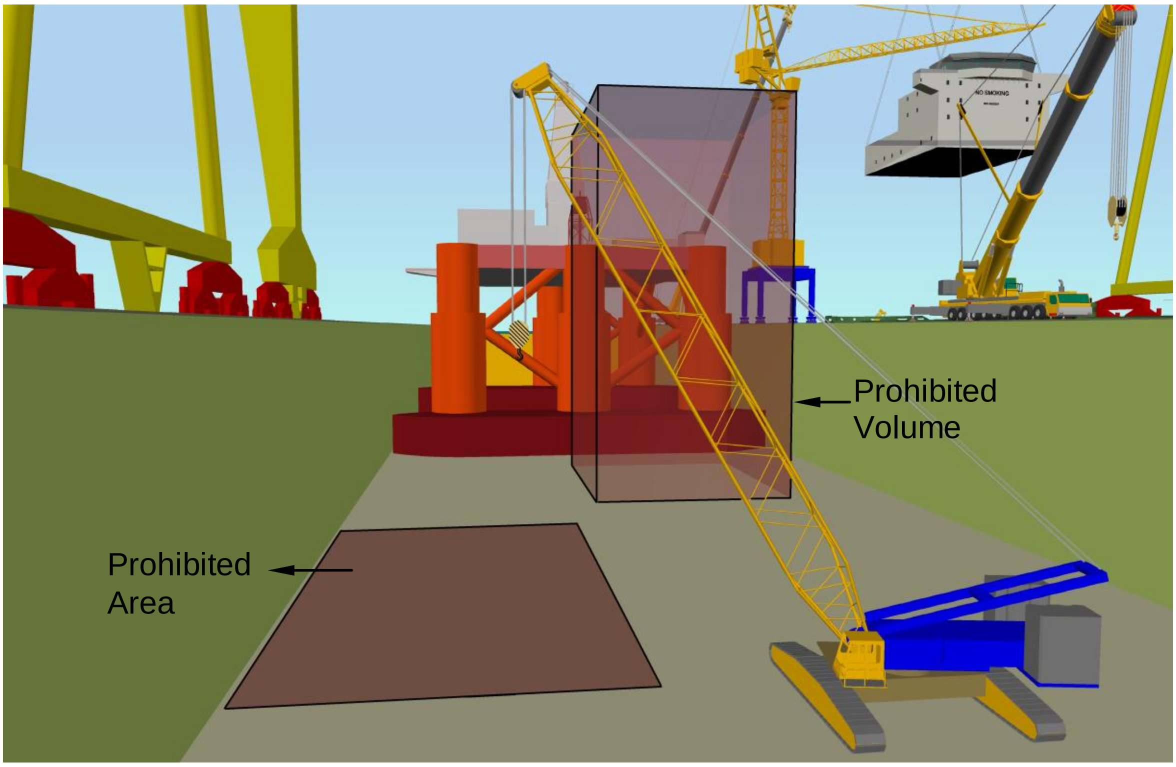

Figure 3. Example of “Prohibited Area” and “Prohibited Volume”.

The user can also insert in the Scenario, in multiple layers, accessories such as jigs, wedges, shims, struts and other elements that are important for planning.

After selecting the Scenario, it is activated the "real-time status Scenario" which, according to the date of the operation that is being designed, will synchronize the following components to reflect their situation in that date: 3D models of works, equipment in its positions, settings and restrictions, prohibited areas and volumes and others.

For example, the user choose to design a lifting operation in dry dock 2 (DS-2) using one of the gantry 1000 tf, named PG-1, on April 12th. The following are the steps to work in the scenario.

a) The Software opens the CAD file of the dry docks scenario which includes the dry dock 1 (DS-1) and dry dock 2 (DS-2), as shown in Fig. 4;

b) All the works and their planned geometry for date and Scenario chosen are shown in 3D (Fig. 4).

c) The position of the second gantry (PG-2) is updated according to its schedule of use that day. If there is interference in the working areas of PG-1 and PG-2, the user is warned, and the priority is given to who carried out the first plan. A negotiation can be requested via the “Manager of Negotiations”.

d) The data of equipment involved for that date, such as safe working load, geometric constraints, location and other temporary restrictions are updated and shown.

e) Prohibited areas and volumes for the specified date are indicated in the Scenario (Fig. 3).

f) Other equipment that is inserted into the scene with its settings, coming from other plans are shown, applying the same procedures of item “c”.

g) The user develop the lift plan of the operation and when completed it is stored in the database to allow its management and technical drawings can be issued, as well as 3D videos.

3.3. Equipment

The lifting equipment can be of various types: telescopic mobile cranes, crawler cranes, pedestal cranes, floating cranes, gantry cranes, overhead cranes, sheer legs, trailers among others.

The lifting devices are modeled in 3D and incorporated into computer models that perform the functions of movement. Basically, they have three translation degrees of freedom (X, Y, Z) for the base vehicle, cabin and boom and one rotational degree of freedom (Z) to the cabin and boom. Each boom has a main hook block and a secondary hook block, both with one degree of freedom for vertical movement. Thus, it is possible to model practically any lifting equipment. For example, a gantry “Goliath” crane vehicle (Fig. 4) will be based on the gantry structure itself, with one degree of freedom to shift along the rails. The cabin is modeled as an object without purpose (dumb solid) and booms represent the trolleys, primary and secondary, which may have two independent winches. The pedestal crane on the top of the gantry is modeled independently and linked to the last by the “Equipment Binding”. For a trailer, the base vehicle is the chassis itself, with three degrees of freedom for translation and three for rotation, without a cabin and booms.

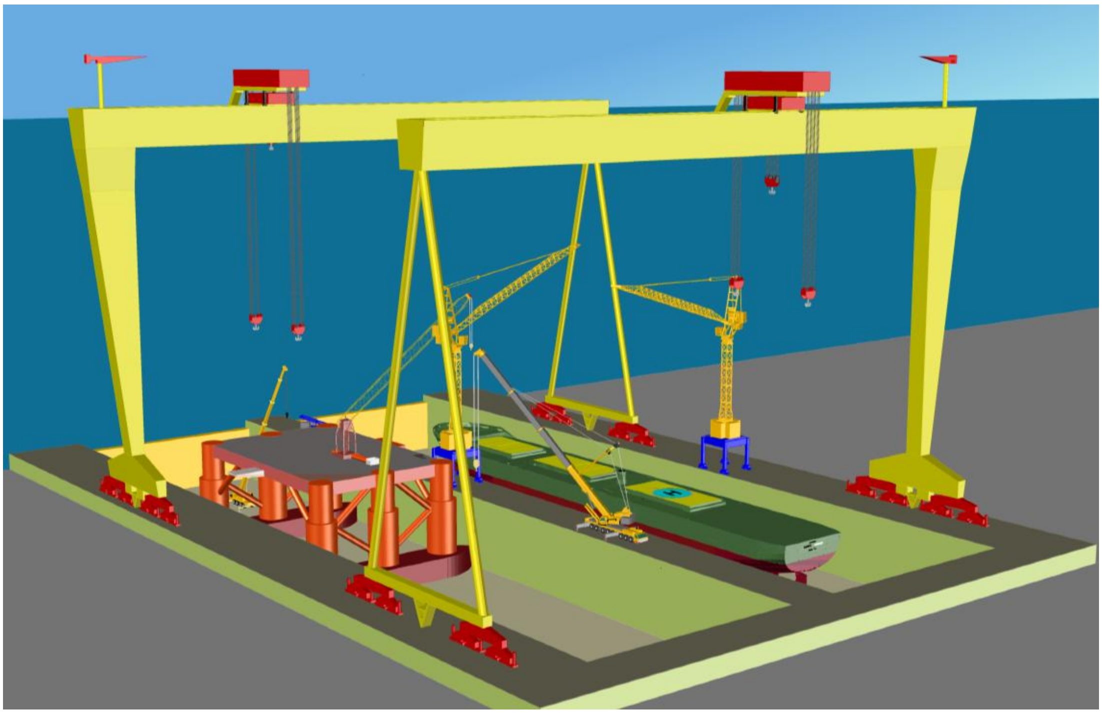

Figure 4. Example of Scenario and lifting equipment.

3.3.1. Equipment Binding

To create more complex equipment or synchronized operations, the user can use the feature "Equipment Binding", where one can perform parametric synchronization with fixed values or mathematical formulas, allowing an absolute link as the auxiliary pedestal on top of gantry crane (Fig. 4), or relative link, such as mobile pedestal crane mounted on the floating dock. The structure allows binding cascade, that is, a device linked to another, the other linked to a third and so on.

In addition to the geometric model and features, for each equipment, in database are stored the load charts and other properties such as self-weight for each configuration, counterweights, types of hook blocks and their safe working load, jibs and its characteristics and others, all based initially on the manufacturer's manual. The user can also add charts for special status such as maintenance, damage or load test.

3.3.2. Design of equipment configuration

For each lifting operation and for each selected equipment, the Software performs the following calculations: safe working load (SWL) of the equipment, counter-weight, safe working load of hook block, required number of parts for hook block cable, maximum allowable speed of the wind, magnitude of force transmitted to the ground by equipment supports, which can be, for example, the force transmitted by the outriggers or crawler tracks in case of mobile cranes, or the force on the wheels of a gantry crane.

The Software will always warn if the user chooses settings unpermitted or outside of the limit range registered in database for the equipment.

3.4. Geometric limitations of operation

This feature prevents the equipment to be placed in improper locations and levels, for example, a trailer or crane to be supported below the floor or a gantry crane be moved beyond the track. It also controls the configured degrees of freedom, not allowing improper movements, for example, a gantry crane move to other direction than the alignment of the track. There is also the verification of operational limitations, preventing, for example, that the inclination angle of the boom reaches values that are not allowed. The warning about the improper positioning is given at the input of data, preventing the user to position or set up incorrectly the equipment.

3.5. Monitor

The "Monitor" is a simulation of the LMI (load moment indicator) screen in the case of cranes, or similar device on other machines, which states in real time, during planning, the values for the operation, such as: configuration of equipment, capacities, geographic coordinates, altitude, direction and others. If the lifting equipment is a floating one, such as sheer leg, information may also include ballast, draft, angles of roll, pitch and yaw. It is an element of optional visualization and the user can choose which information will be shown. For viewing the "Monitor", a CPU with multiple monitors is used, preferably three, where one of them shows the scenario, another one shows the control panel, and the third shows the "Monitor". Optionally, the "Monitor" can stay on the same screen of the scenario, configuring the monitor to have an invisible background for better viewing.

3.6. Equipment Settings Report

In the management phase, one of the reports issued is the "Equipment Settings Report" based on the date which the lift will be done. It reports, for each equipment that will be in the area of operation, the geometric configurations that should be adopted for no interference, such as position, rotation, boom extension and angle ranges and other configurations.

This report aims to help set up the equipment to stand in a certain configuration, on a specific date to avoid interferences and collision risks.

3.7. “Equipment Schedule” feature

The "Equipment Schedule" feature is used to check if certain lifting equipment is available on a certain date. If it is busy, the Software shows who made the reservation and when it will be available again. The user can use the "Manager of Negotiations" feature to reverse or change the reservation. This function makes the reservation of the equipment and it is also possible to impose restrictions of use for maintenance, inspections, load tests and others.

4. DESIGN

Through the “Design’’ module, special lifting accessories are designed and detailed, such as pad eyes, trunnions, spreaders and others, issuing the calculation results, the 3D models and technical drawings. It also performs the selection and checking of usual accessories, such as shackles, master links, hooks and others, detailing it in 3D (Fig. 5).

This module also designs wire rope slings of various types and geometries (Roncetti, 2011): single leg, two, three and four-legged slings, grommets, braided slings and cable-laid slings. Reports are issued with all the calculations, and it is also made a detailed 3D model, incorporating the special accessories or usual lifting accessories as shown in Fig. 5.

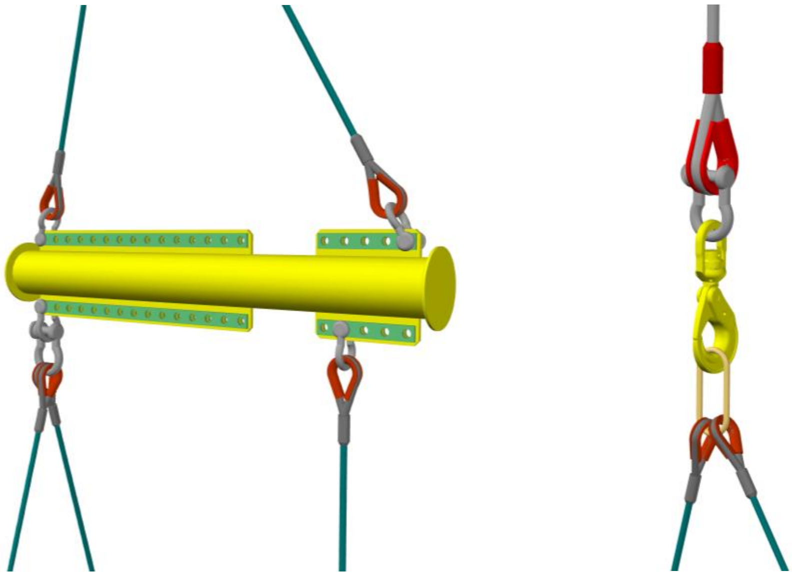

Figure 5. 3D model of slings, spreader and usual lifting accessories.

In this module, the user can do the calculations for upending or turning blocks and other parts, calculating the sharing of forces among the equipment involved in the lifting.

This module is also responsible for the generation of technical drawings of the calculated elements and the worked planning, which is usually called “rigging plan” or “lifting plan”. Examples are shown in Fig. 6 and Fig. 7. These documents are essential to the success of operations as stated by Roncetti (2010b).

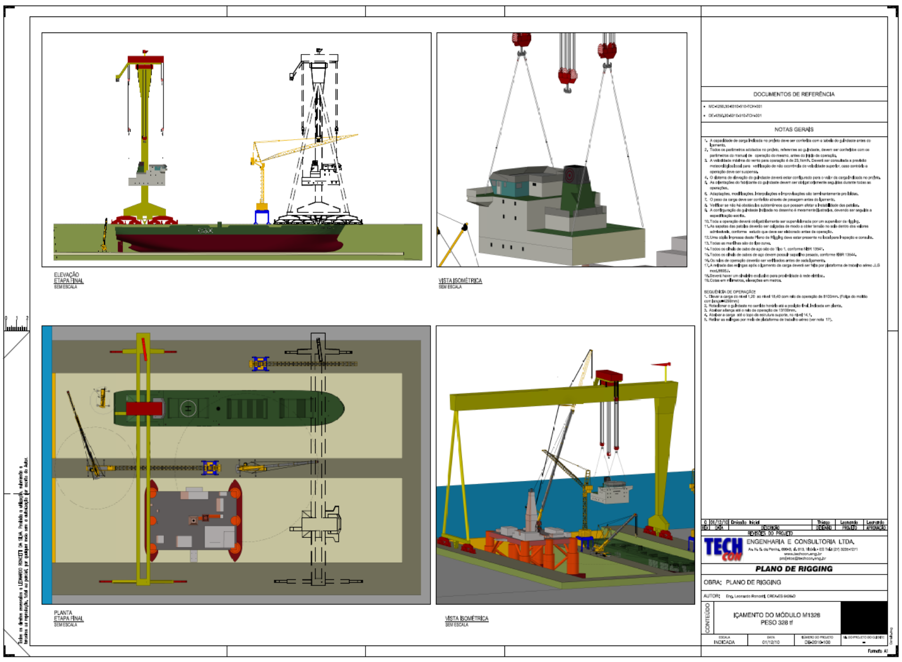

Figure 6. Lifting plan for a heavy block generated by the “Design” module.

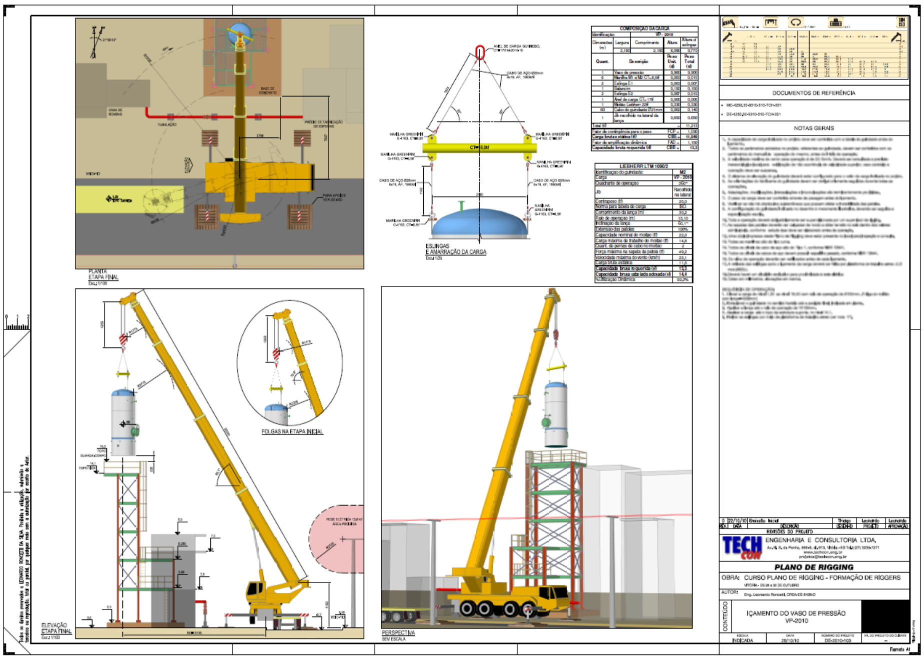

Figure 7. Lifting plan for a pressure vessel generated by the “Design” module. (Roncetti, 2010a)

5. PLANNING

In the “Planning” module, the goal is to plan, simulate and test the lifting situations within the chosen scenario, and then generate the necessary information for the management and execution. The user can execute any movement with the involved equipment in real time, leading to an automatic movement of lifted loads and attached elements. The errors, limitations and restrictions, if any, are immediately reported to the user.

The user can do the simulation of the trajectory of the lifted loads from its starting point to its final position by the following manners: a) manual - the user manipulates the position of the equipment and the loads are positioned as the configuration adopted; b) determine a "load-path", where the equipment is automatically configured to move the load along a path defined by the user; c) automatically, depending on the operation that the user is performing, as an example, the upending or overturning of a module, where the Software operates the cranes to execute the operation, showing the values for capacities. In any case the capabilities of the equipment and the safety criteria are always verified.

5.1. Collision Detector

The "Collision Detector" feature alerts whenever objects contact each other or there is any interference. The "Proximity Detector" alerts whenever the loads or equipment are at a distance less than the configured one.

5.2. Negotiation Manager

The "Negotiation Manager" feature is used to manage the attempts to solve interference, overlap, booking and any other conflict situation. When the planning needs to use a volume or area reserved for storage, operation, maintenance or other restriction that does not allow the lifting, the Software shows which user has made the booking, the propose and the schedule. If these regions are subject to negotiation, the Software asks the user who made the booking if these areas may be released. If positive, the database is updated. The same procedure can be made in case of equipment and accessories.

5.3. Technical Drawings

Once the planning is finished, CAD platform generates the technical drawings that will guide the operation and management. Figure 6 and 7 show examples of technical drawing of a rigging plan or lift plan.

5.4. 3D Animation

The animation of operations is very important for planning, making it easier to understand and verify the feasibility of more complex situations and scenarios.

The “3D Animation” module uses the CAD platform to generate animations of all operations of lifting and handling. In one video, the user can choose any number of views (camera positions) that are necessary (Fig. 8). For example, the user can divide the screen into a camera in the cabin operator, another camera for top view and another for side view. He can also choose a single view (Fig. 9). The software allows, during the production of video sequences, the change of position, focus and target of cameras. The user can also link the camera to the equipment and loads so that they follow the movement of these.

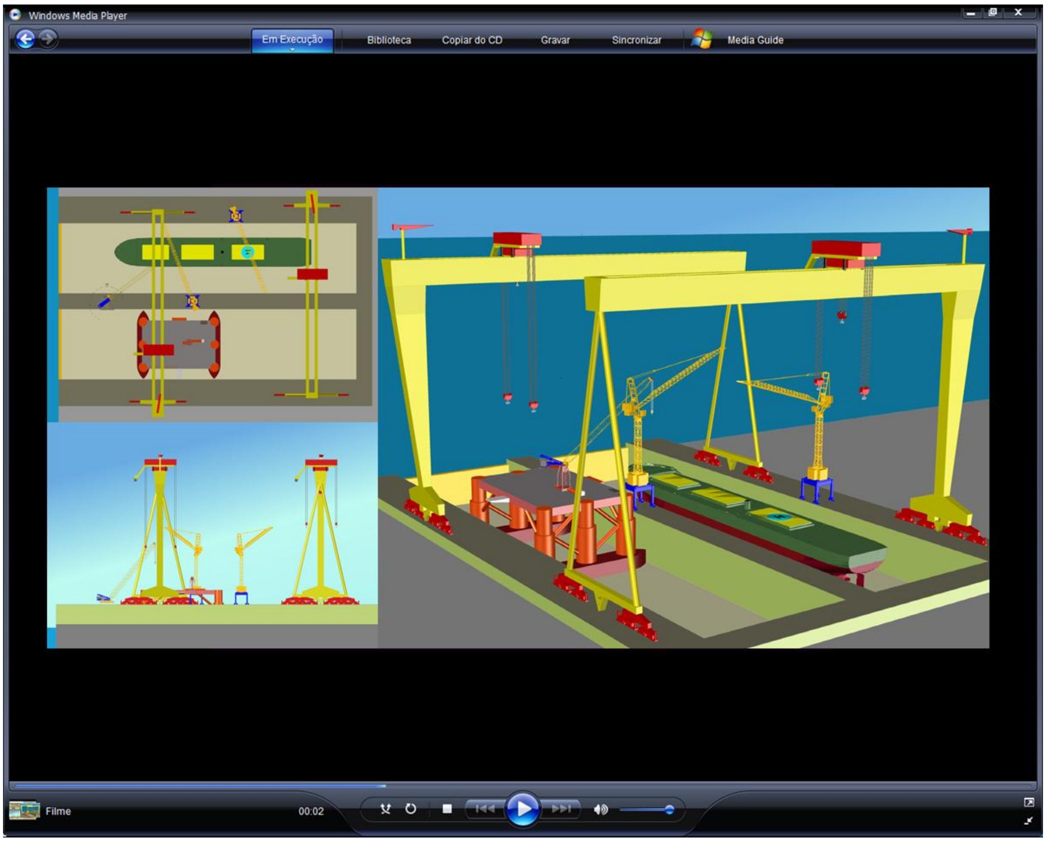

Figure 8. Animation of operation showing top view, left view and perspective view.

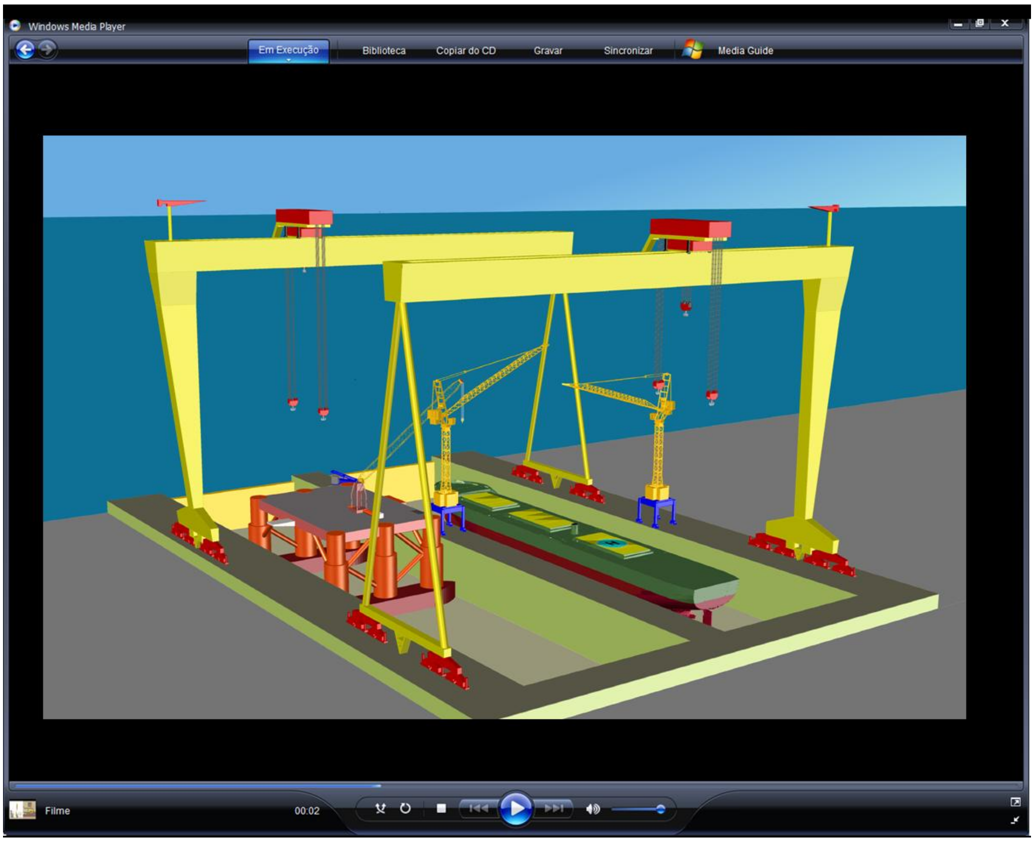

Figure 9. 3D Animation of operation perspective view.

6. MANAGEMENT

The “Management” module generates reports of operations, histograms, schedules, reports of booking of equipment and others. The user can also generate custom reports.

6.1. Inventory, inspection and testing

These modules manage the recording and control process of inventory, inspections and tests for equipment and accessories of lifting and handling. The inventory module provides the basis for the other two, recording the items and also serving as inventory control. The user can manage inspections and tests on lugs, trunnions, slings and other components, generating the appropriate reports. The results of the inspections and tests are inputted in the Software, that interprets them, issuing a final result according to the type of inspection or test, and may indicate for example, whether a sling should be discarded. The Software sends alerts about the deadlines for inspections, generating management reports.

6.2. Teaching and training

Due to its graphical interface in 3D virtual reality and realistic movement of equipment, the Software can be used for training the staff that will conduct the planning and management, simulating different situations that will facilitate teaching and learning.

7. CONCLUSIONS

Through the features of the Software, it is concluded that lifting operations for shipbuilding and offshore construction are very complex and risky and really need integrated software to help design and management.

The proposed Software, with specific features for heavy lift design, planning and management fulfill shipbuilding and offshore construction industry requirements improving safety, control, quality, speed and other important factors to maximize competitiveness.

This Software, though powerful, extensive and complex, primarily indicated for large shipyards, can be installed in smaller ones and even in companies that have only a few equipment, as its modular structure allows installing only the basic modules and the necessary features.

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