# Integration of Extracted Data for Ship Block Construction

**Ernest L S Abbott[1], Zhuo Liu[2], David K H Chua[3], and Fan Jiang[4]**

## Abstract

Using a database that has been built from extracted Tribon data creating and a customized 3D view of the block provides for improved engineering experience in the perception of a block's construction. Identifying the topological relationships between the various component parts that compose a ship's block enables the automatic location of the ideal positions for lifting lugs. This paper presents the ongoing research on the integration of extracted design data from Tribon for ship block production and construction. Specially, an automation of lifting lug placement for ship block assembly is developed as a heuristic problem based on the extracted and integrated design data.

## Introduction

Tribon is not a single program, but suite of programs that access a common set of databases that contain the design details of ships or semi-submersibles. The databases contain not only design details, but also such things as structural elements, pipe segments and equipment.

Tribon is used in 85% of the world's top 20 shipbuilders (AVEVA, 2005a)) and clearly plays a significant part in the design and production process or the marine and off-shore industry.

Literature review has revealed very little work on the use of Tribon data outside a Tribon environment. Published work has focused on the weaknesses of Tribon as a CAD system in the design stage (Roh & Lee, 2007), the extraction of equipment model digital data from Tribon (Hwang et al, 2004) and the exporting of Tribon model data in Autodesk's DXF format which is then imported to 3DS Max, a commercial software (Li, 2003). Besides, Kim et al. (2005) introduce a PC-based off-line programming method based on Tribon interface. Zhang et al. (2009) also extract the hull structure information from Tribon for the further operational use. Li (2010) develops an open framework to integrate Trion and Spar. The use of commercial software to view a 3D model has its limitation because it is just a viewer/updater and does not provide any reasoning capabilities.  Further, DXF does not hold useful engineering information such as the weight of the constituent parts or their centre of gravity.

There seems to be a few commercial applications extracting data from Tribon, one should be noted, namely, Deltatools (Delta, 2010), which extracts Tribon nesting data for cutting.

[1] Research Engineer, Dept of Civil Engineering, National University of Singapore, 10 Kent Ridge Crescent, Singapore, 119260, (65) 65162195, FAX (65) 67791635 Email. cveaels@nus.edu.sg.

[2] cveliuz@nus.edu.sg, Research Fellow, Dept. of Civil Engineering, National University of Singapore, 10 Kent Ridge Crescent, Singapore, 119260, (65) 65162195, FAX (65) 67791635 Email. cveaels@nus.edu.sg.

[3] cvedavid@nus.edu.sg Associate Professor, Dept of Civil Engineering, National University of Singapore, 10 Kent Ridge Crescent, Singapore, 119260, (65) 65162195, FAX (65) 67791635 Email. cveaels@nus.edu.sg.

[4] Executive, Jurong Shipyard Pte Ltd. 29, Tanjong Kling Road. Singapore 628054. DID (65) 6262 7030 Email. Jiangfan.dnd@jspl.com.sg

Data extracted from Tribon databases using Tribon's Python based scripting language Vitesse is loaded to a relational database. Once the data is loaded into a relational database, it is possible to use the data to improve the working experience of production engineers.

A few areas have been identified where this improvement can be made. The first is in the locating of lifting lugs. The locating of lifting lugs is important for safety reasons. The lugs have to be located so that the tensions across the 4 wire ropes used are fairly evenly distributed. The angle between the ropes must be with in prescribed safe limits. The lugs must be placed so that the block is lifted as near as possible to being level. In addition, the lugs must be located at suitable points on the block so that the block is able to take the strain of the lift. Different block configurations require different methods for locating of the lug positions.

A second area is to simulate the effects of the removal of parts of the block on its centre of gravity and weight. On some occasions, it may be necessary, because of space constraints or crane lifting constraints, to remove panels or pillars for the normal construction process in the workshop. Any removed parts will be added at a later stage in a different location. Knowing the excluded objects weight and centre of gravity, updated weights and centre of gravity may be automatically calculated. This enables an engineer to decide the best parts of a block to remove at the point of workshop construction.

This paper begins with the construction of a database from data extracted from Tribon. It covers the building processes necessary for making the data usable. It then explains how the various parts are connected and mapped in preparation for further processing. It gives a brief comment on the 3D visualization of the data. This is followed by the rules for locating lifting lug positions and some general constraints.

The procedure for the automatic location of lifting lugs for what is termed *double-bottom hulls* is explained along with the method used to calculate the rope tension. This is followed by the procedure for the automatic location of lifting lugs for what is termed *open hull*.

The procedure which is common to both *double-bottom hulls* and *open hulls*, that of the location of lugs for overturning purposes, is covered.

## Uploading Extracted Data

Data extracted from Tribon is uploaded to a relational database. The extracted data consists of various Tribon objects: Blocks, Panels, Plates, Stiffeners, Brackets, Pillars Flanges, Curved Panels and Curved Stiffeners. Blocks comprise of panels; panels are made up of plates. Stiffeners, Brackets and Pillars are associated with a plate. Curved Panels and Curved Stiffeners are associated with the Block. See figure 1 for schematic.

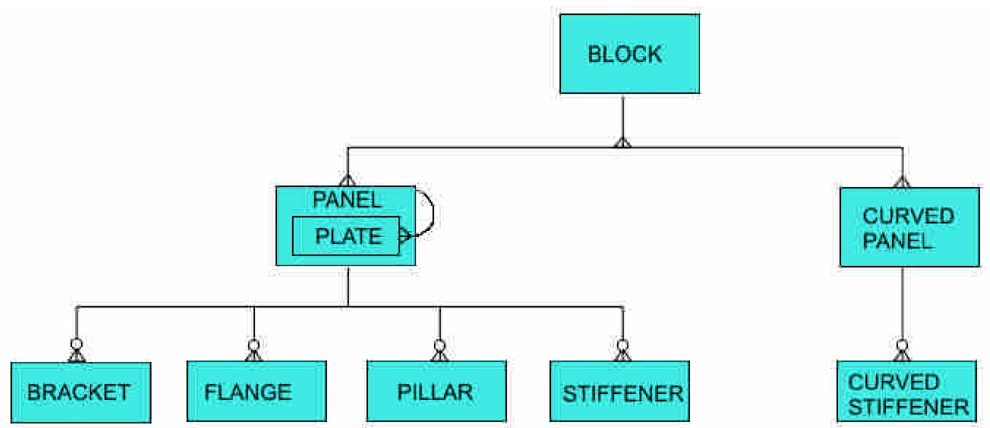


Figure 1. Object Relationships

During the uploading process, a number of calculations and identifications are performed. The centre of gravity of the block is calculated from the panels that constitute the block; Tribon does expose the block's centre of gravity. Since the extracted data contains the centre of gravity for panels, as well as component parts, it is a simple matter of using the standard method of calculating the centre of gravity of several joined parts:-

$$R = \frac{\sum m_i r_i}{\sum m_i}$$

Where *R*= centre of gravity, $r_i$ is the centre of gravity of the component part and $m_i$ is the mass of the component part.

The blocks bounding box is calculated by, during the uploading process, using the plates and panels dimensions, since Tribon does not expose the bounding box dimensions for a block. Using these dimensions, the blocks orientation is identified. The uploading program uses the two longest edges of the bound box to identify the plane the block is in. (When they are constructed, blocks will have their largest area as a base.) For example, a block with its longest edge in the Y direction and next longest edge in the X direction is said to be in the XY, and to make the distinction between this and block whose longest edge is in the X direction and next longest edge is in the Y direction, the uploading program adds a suffix. In the first case, the orientation is XYY and in the second case, the orientation is XYX.

Panels, stiffeners and flanges are treated in the same way as blocks, in identifying their orientation. A panel's orientation is derived from the plates that go to make up the panels because the bounding box data for panels from Tribon includes all the components that are associated with the panel.

Panel identification is further subdivided. Panels that are in the plane of orientation are defined as panels. Panels that are not in this plane are either *Bulkheads* or *T-Griders*, see figure 2 to see the difference. T-Griders have flanges along at least one edge of the panel. Bulkheads divide the block, (Definitions).

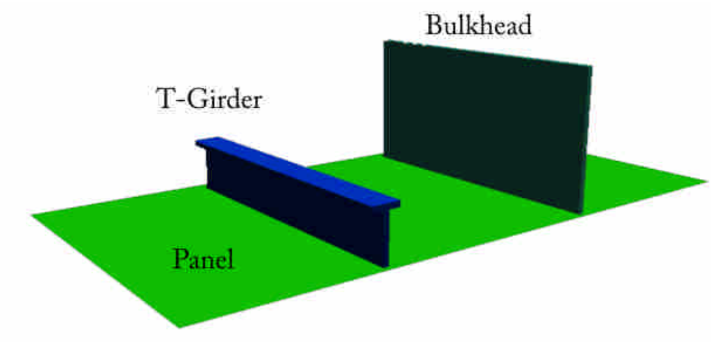


Figure 2. Example of Panel, T-Girder and Bulkhead

The research identified two broad categories of blocks: double bottom and open hull, see figure 3 for examples. The identification is arrived at by examining the number of panels in the same orientation as the block and the position of the panels relative to the bounding box of the block.

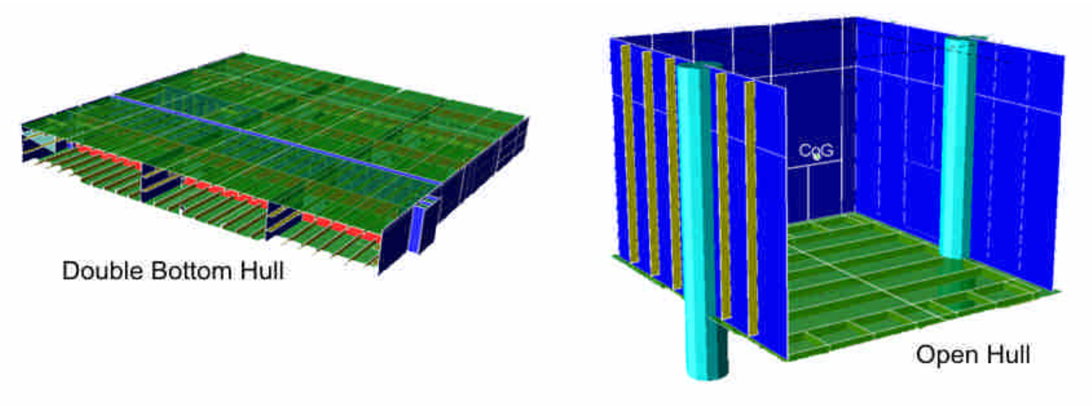


Figure 3. Double Bottom and Open Hulls

## Building Connection and Intersection Data

For each panel, including bulkhead and T-girders, a list or what it connects and where it connects with is built. For T-girders and panels, the connection can be at either or both connection edges, as in the case of a bulkhead on a double bottom block, it will connect to an upper and lower panel.

Once the connection data has been assembled, the list of connections is processed for intersections. A separate list is built holding just the intersection data. The list contains the panel identities and types, the coordinates, the block quadrant the intersection occurs in, see figure 4.

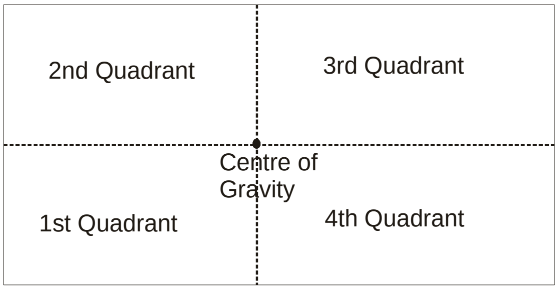


Figure 4. Division of Block into Quadrants

## Using Tribon's Extracted Data Database

The extracted data database is used to build a 3D model using HOOPS as the rendering engine and C# as the programming language that an engineer may interact with. To enable the engineer to interact with the 3D model, and to be able to automatically identify potential locations for lifting lugs, the relationships between the various constituent parts have to be established.

Every panel, and this includes T-girders and bulkheads, will be connected to other objects such as other panels, T-girders, bulkheads, flanges, stiffeners, pillars and brackets. These connection relationships are identified when a blocks data is read by the supporting software.

## General Rules for Lug Location

The following rules are based on interviews with experienced technicians in a local shipyard. Lifting lugs have to be located at a point where the structure is able to support the lift. For double bottom blocks, the strong points are where panels intersect with panels, bulkheads intersect with panels or bulkheads intersect with bulkheads. For open hull blocks, the points of lift are adjacent to a bulkhead.

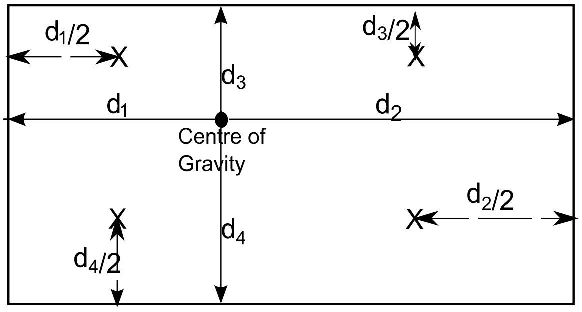


Figure 5. Ideal Location of Lifting Lugs

Figure 5 shows the ideal locations for lifting lugs. In figure 5, the centre of gravity is not at the centre of either of the side. The distances from the centre of gravity to the left edge is $d_1$, to the right edge is $d_2$, to the top edge is $d_3$ and to the bottom edge is $d_4$. The location of the lugs is half the distance from the centre of gravity to the edge ($d_1/2$, $d_2/2$, $d_3/2$, $d_4/2$). The 4 locations are indicated by X in figure 5.

The angles between the wire ropes are required, for safety reasons, to be between 30° and 60°. This is the angle the rope makes with the adjacent ropes. Figure 6 shows an example of a double bottom block with ropes.

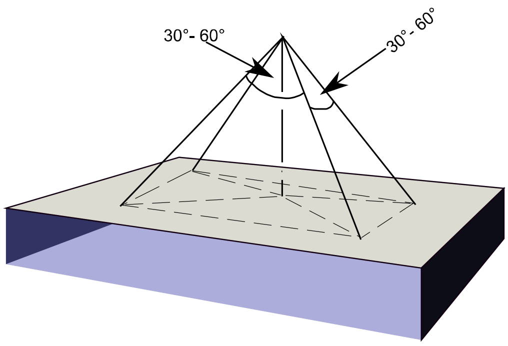


Figure 6. Constraint of Rope Angles

## General Constraints

There are several constraints to consider when locating positions for lifting lugs. First, there are the rope lengths to be used. Ropes come in fixed lengths, but they may have extensions and also shackles. The size of the shackle varies according to the weight that has to be lifted. Second, there is the hook height from the ground level. Workshops have fixed ceiling heights so the rope length has to be such that there is sufficient room above the hook in the initial lift position to make the lift. Third, the block must be lifted so that the angle along the length of the block does not exceed an amount preset by the engineer, usually between 0.5° and 3.0°, this is called *slip angle*. Fourth, lug locations cannot be too near to the centre of gravity as this tends to instability when lifting. A practical distance is one-half of the width of the shortest side of the block, but this value is able to be varied by the engineer. Fifth, the lifting hook is always located vertically above the centre of gravity.

## Automatic Lug Location for Double Bottom Hull Blocks

The algorithm for locating sets of lifting lugs, as the sets come in 4, has a number of steps. The first is examining each intersection point on the block at the surface where the lifting lugs are to be placed. For each point of intersection, all combinations of ropes, with rope extensions and shackles, are used to calculate the hook height that would result, see figure 7. Since the location of the centre of gravity, the distance from the intersection point and the length of the resultant rope length are known, the height is calculated as follows:-

$$H^{2} = RL^2 + D^2 - 2 \times RL \times D$$

Where H = Hook Height, RL = Rope Length, D = Distance in the plane of the point of intersection to the line of centre gravity.

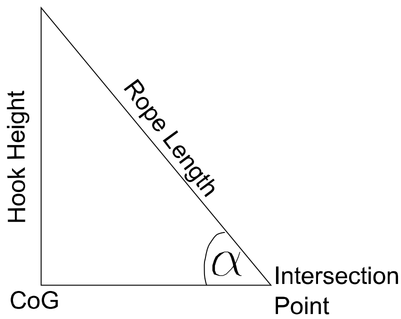


Figure 7. Calculation of Hook Heights

For each crossover point, a list of rope lengths, corresponding hook heights and rope angles, α, are stored within the list of intersections. The second step is to search the created lists looking for points that have matching hook height. The search starts by looking at every crossover point in quadrant 1, then looks for a matching hook height in quadrant 2, then looks for a matching hook height in quadrant 3, then finally in quadrant 4. The crossover points may have the same hook height but not the same rope length[5]. These points are used to create a tree, as may be seen in figure 8. Figure 8 shows that for any node, there may be several crossover points in the next adjacent segment that has the same hook height. At the creation of the search result tree, a node is created up to the point of failure. A path in the tree may not have all 4 nodes. The third step is to purge the tree of incomplete sets of paths, i.e. paths that do not have 4 nodes on them. The fourth step is to calculate rope tensions; this is discussed in details following. The fifth step is to eliminate all sets where the rope tensions exceed the maximum lug weight. The sixth step does not eliminate any sets of points, but applies weighting criteria to the sets of points. This ranks the sets of points for usefulness. The ranking criteria relates the location of the crossover point; if it is over the intersection of two panels, it receives a higher ranking than if the crossover point is over a bulkhead and T-girder. The length of ropes used is also ranked with ropes of equal length receiving a higher ranking than all ropes being of unequal length. The final decision for the selection of the lug location points to use is that of the engineer. The ranking helps in this decision making. The final step is to remove any duplicate values from the list.

[5] Rope length here means the total rope length, including any extensions and shackles.

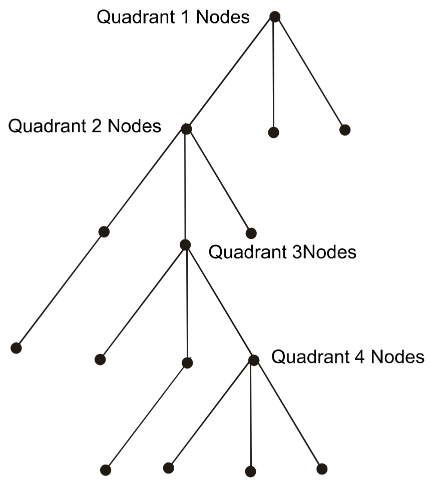


Figure 8. Quadrant Node Tree

## Calculation of Rope Tensions

The system of 4 ropes acting at a point, the hook, is an indeterminate system (Crandal et al 1978, Choi, 2005). We introduce additional factors to solve this problem. We note that, following figure 9, $W = T_1\cos\alpha_1 + T_2\cos\alpha_2 + T_3\cos\alpha_3 + T_4\cos\alpha_4$ (Equation 1)

The elongation of a rope, using Hooke's law is given by $\delta = \frac{Tl}{EA}$, where $T$ is the tension in the rope, $l$ is its length and $EA$ is the extensional stiffness of the ropes. Assume that the ropes are of an identical material and have an identical extensional stiffness. The extension in the vertical direction for 4 ropes, assuming that the vertical extension is small, and the same is given by:

$\delta_1 = \delta_h \cos\alpha_1$ $\delta_2 = \delta_h \cos\alpha_2$ $\delta_3 = \delta_h \cos\alpha_3$ $\delta_4 = \delta_h \cos\alpha_4$ , which may be rewritten as $\delta_n = \frac{\delta_1}{\cos\alpha_1}$ $\delta_n = \frac{\delta_2}{\cos\alpha_2}$ $\delta_n = \frac{\delta_3}{\cos\alpha_3}$ $\delta_n = \frac{\delta_4}{\cos\alpha_4}$. Hooke's law for the elongation of the rope 1 can be written as $\delta_1 = T_1\frac{l_1}{EA}$ , and similarly for ropes 2,3 and 4. Hence,

$$\frac{T_1}{l_1\cos\alpha_1} = \frac{T_2}{l_2\cos\alpha_2} = \frac{T_3}{l_3\cos\alpha_3} = \frac{T_4}{l_4\cos\alpha_4} \qquad \text{(Equation 2)}$$

Substituting in Equation 1, and solving W in terms of $T_1$,

$$W = \frac{T_1}{l_1\cos\alpha_1}(\cos^2\alpha_1 + l_2\cos^2 a_2 + l_3\cos^2 a_3 + l_4\cos^2 a_4)$$

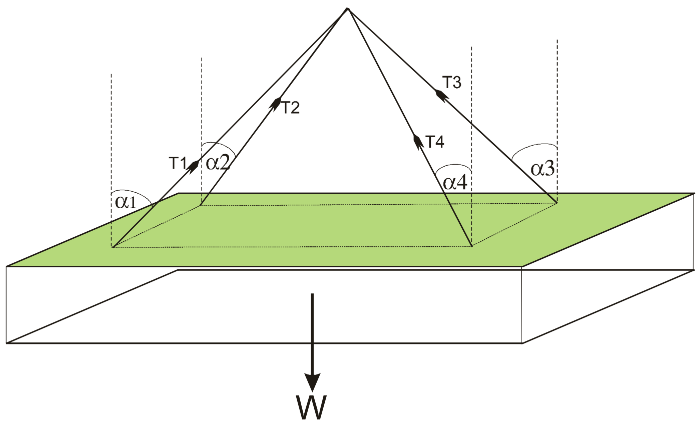


Figure 9. Rope Angles and Resolved Tensions

## Automatic Lug Location for Open Hull Blocks

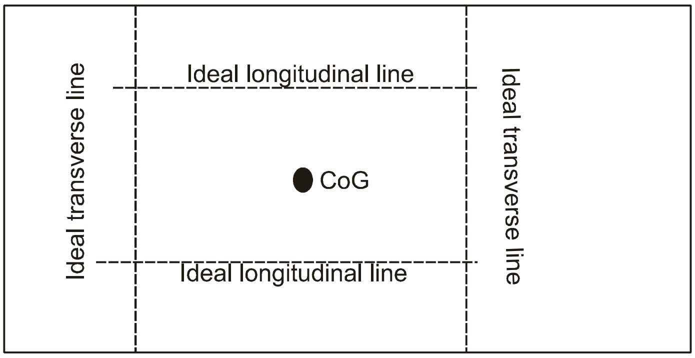


Figure 10. Ideal Lines Open Hull For Lug Location

From the ropes, rope extensions and shackles available and constraining the angle between the ropes to be between 30° to 45°, the minimum and maximum possible distance between adjacent lugs is calculated. The search for suitable points begins in quadrant 1 (refer to figure 4) along the longitudinal ideal line beginning at a distance of half the minimum distance from a transverse line that passes through the centre of gravity. Half the minimum distance is chosen to approximate to symmetry,

The search is for transverse bulkheads, T-girders and stiffeners; when found, the lug location is always placed at the base of the bulkhead, T-girder or stiffener on the same side as the centre of gravity.

For each suitable point found in quadrant 1, a search is made in quadrant 2 for suitable point, taking into account all the constraints mentioned above. If a suitable point is found, then the process continues to quadrant 3 and quadrant 4. When a set of 4 suitable points have been identified, the rope tensions and weights as per the double bottom hull are calculated. The results are presented to the engineer who has the final decision as to which set he will use.

## Semi-Automatic Lug Location for Open Hulls

A third computer aided method for locating lifting lugs has been termed 'semi-automatic'. The semi-automatic method requires the engineer to select the rope length and location of the first lifting lug. The block is still viewed as having 4 quadrants. If the engineer selects a point in quadrant 3, the search for the next point is performed in quadrant 4. If the initial selection is in quadrant 4, the search for the next point is performed in quadrant 1.

Given a lug location and rope length, the hook height can easily be calculated, see figure 7. The search for the next point uses the fixed hook height, then each rope, rope extension and shackle extension are used as generator of a cone whose apex is the hook point. (Figure 11, shows the projection of the search area.) The 'other end' of the rope meets on the block surface. Where it meets, a check is carried out to see if it is adjacent to a bulkhead, T-girder, or stiffener. If it is, then this is a possible point and it added to a list of possible points that will be presented to the engineer for selection. For presentation purposes, the engineer is shown the angle the rope makes with the adjacent rope. No tension calculations are carried out until all 4 points have been selected.

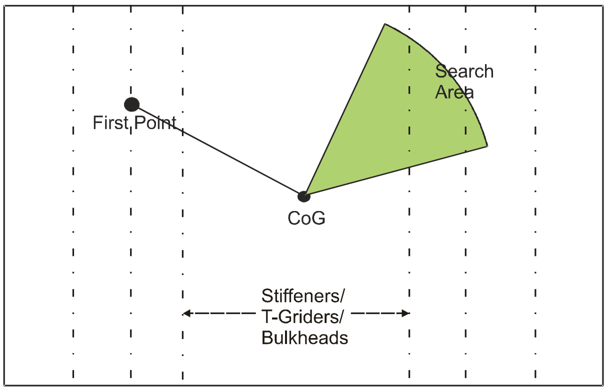


Figure 11. Projection of Search Area

## Location of Lugs For Overturning

The lug locations for overturning are always on the edged of the block. These will be located where the transverse idea line intersects the longitudinal edge at the nearest bulkhead, T-girder or stiffener. In cases where the block is very heavy[6], two additional lugs are required, each is placed between the ideal position and the end of the block.

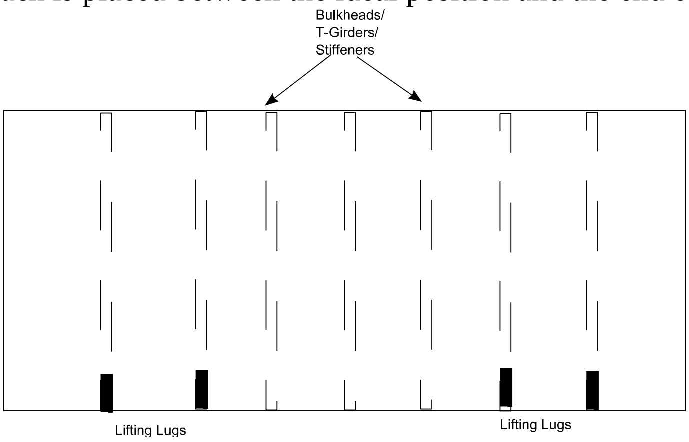


Figure 12. Location of Overturning Lugs

## Conclusion

Using Tribon data that has been loaded into an external database builds a firm basis for extending the use of Tribon design data beyond the boundary of the design engineers to the production engineers. It leads easily to enhanced usability of Tribon topological and design data, giving the production engineer improved productivity tools. These tools allow the full 3D view of the block, then enhancing the engineer's perception of his work.

[6] Heavy is relative term here and would depend on the equipment capacity, among other things.

Specially, an automation of lifting lug placement for ship block assembly is developed as a heuristic problem based on the extracted and integrated design data. The manual, automatic and semi-automatic positioning of the lifting lugs removes the necessity for possible error prone manual calculations.

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