International Journal of Offshore and Polar Engineering (ISSN 1053-5381)

Vol. 15, No. 1, March 2005, pp. 62–64

Lifting Analysis for Heavy Ship-hull Blocks Using 4 Cranes

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An analytical approach is discussed for the calculation of 4 lifting forces for heavy ship-hull blocks, considering elongations of lifting slings. Besides the force and moment equilibrium equations, a compatibility condition is introduced to determine 4 unknown lifting forces. A ship-hull block with field measurement is analyzed, and the result shows that the information obtained by the current method could be useful for engineers in conducting similar lifting work at shipyards.

INTRODUCTION

In small to midsize shipyards, generally 1 to 4 cranes are jointly used depending on the weight of the block, but the maximum block weight that can be lifted by combined cranes is based on a 3-crane utilization plan. If the lifting force of each individual crane is insufficient, or if the block-lifting task is difficult due to the arrangement of the cranes in the shipyard, 4 cranes are occasionally used in the case of heavy hull blocks. This study focuses on solving the block-lifting problem using 4 cranes. In addition to the 3 static equilibrium equations, an additional condition considering elongations of the lifting slings has been proposed. Further, this method was applied to find the change in lifting force of the slings due to the inclination of the hull block that occurs when it is being lifted or moved.

LIFTING ANALYSIS FOR SHIP-HULL BLOCK

The equilibrium condition consists of 1 force equation in a vertical direction and 2 moment equations in relation to the rotation about the x and z axes (Crandall et al., 1978). The lifting forces and the location of the tension points of the block being lifted by 4 lifting slings are $\vec{T}_\alpha$, $\vec{r}_\alpha$ ($\alpha = 1, 2, 3, 4$), respectively. The weight of the block and its center of gravity are $\overrightarrow{W}$ and $\vec{r}_c$, respectively.

$$\overrightarrow{W} + \sum_\alpha \vec{T}_\alpha = \vec{0} \tag{1}$$

$$\vec{r}_c \times \overrightarrow{W} + \sum_\alpha \vec{r}_\alpha \times \vec{T}_\alpha = \vec{0} \tag{2}$$

Because the location of the center of gravity changes according to the rotation of a large hull block with substantial dimensions, the effect of the inclination is emphasized. The equilibrium condition of an inclined block can be expressed by substituting $\vec{r}_c$ and $\vec{r}_\alpha$ with the position vectors after the coordinate transformation.

The calculation of 4 crane lifting forces is a redundant problem, which cannot be determined by static equilibrium equations alone. An additional condition is needed apart from the 3 conditions for force and moment equilibrium. This can be done by introducing a condition for elongation of the lifting slings.

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Received April 15, 2004; revised manuscript received by the editors October 26, 2004. The original version was submitted directly to the Journal.
KEY WORDS: Cranes, ship-hull block lifting, statically indeterminate problem, angle of inclination.

The elongation of the lifting sling is calculated by Hooke's law:

$$\delta = \frac{Tl}{EA} \tag{3}$$

where l is the fixed length of the crane lifting sling, T is the tension in the lifting sling, and EA is the extensional stiffness of the sling. Hence the distance H, from the ground to the end of a crane boom, is:

$$H = l + \delta + h \tag{4}$$

In Fig. 3, y' is the distance from the bottom of the block in an elongated state to the original position of the lug when the lifting sling is not elongated. Thus:

$$\delta = \frac{T}{EA}(H - a - y') \tag{5}$$

Because the block is assumed to be a rigid body, even when the block is in a lifted state it can be seen that its 4 lug points are located on the same plane, i.e. the horizontal plane based on the highest lug position when the block is on the ground. The difference between this imaginary plane and the actual location point of the lug seems to be very small compared to the length of the lifting sling, so those elongations are disregarded. The straight lines that join the 4 lug points on the imaginary plane can be expressed by 3 position vectors. Thus the additional compatibility condition requires that the position vectors of the lugs have to be located on the same plane.

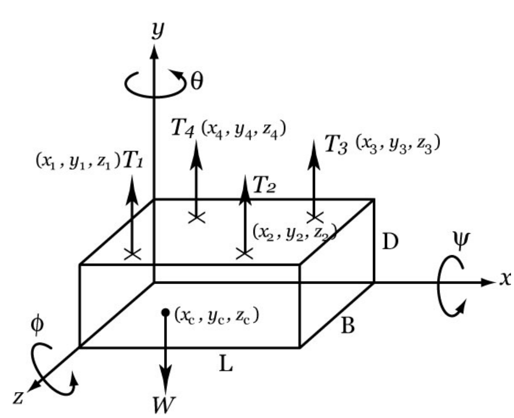

Fig. 1 Three-dimensional hull-block model with 4 lifting slings