Safety Analysis of Boom’s Maintenance Rack of the Ship Loader During Ro-ro Progress

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Abstract. In order to ensure the safety and stability of the transport process, improve the efficiency of transport, using the whole machine ro-ro transportation is an advanced, efficient and economical means of transportation to the ship loader. Due to all kinds of potential safety hazard during ro-ro progress, it is necessary to do safety analysis of the ship loader. Focusing on the safety analysis of boom’s maintenance rack of the ship loader, in this paper, firstly static analysis of the boom’s maintenance rack was carried out by using software ANSYS; and then the safety of boom’s maintenance rack was analyzed; at last, corresponding improvement methods were proposed for the scheme, and correlative conclusions were obtained.

Introduction

On account of large volume and weight, and with the limit of traffic capacity of road and bridge during the transport, it’s hard to transport the ship loader by land, so in a way, transporting by sea is the only way. In order to ensure the safety and stability of the transport process, improve the efficiency of transport, using the complete machine ro-ro transportation is an advanced, efficient and economical means of transportation to the ship loader, but at the same time we must pay attention to the danger during the transport, slight incaution will cause a serious accident [1]. Due to all kinds of potential safety hazard during ro-ro progress, it is necessary to do safety analysis of the ship loader.

Boom’s maintenance rack is installed under fixed arm of the ship loader, about 16 m high, 22 m wide, 60 t heavy, mainly comprises of major structure and mainframe connecting rack, and major structure is made up with box girder, and connecting rack consist of circular hollow beam, the walking trolley is installed under the major structure, and hinged with mainframe by connecting rack, its function is transporting crews and equipment when boom system is needed to be adjusted and maintained. Boom’s maintenance rack goes forward together with the ship loader during ro-ro progress.

Static Analysis

Kingpost of the boom’s maintenance rack is composed of box beam (1000 mm×1000 mm) which is welded by 12 mm thick steel plates, and there are stiffened plates in the middle of the kingpost, which have a certain bearing capacity. Usually there is no other accessory equipment on the maintenance rack, and the maintenance rack doesn’t bear loads. According to the static analysis result of the complete machine of the ship loader, under the self-weight load of fixed arm and telescopic boom, the stress is larger in the front of the swaying rack, so when designing ro-ro scheme, it’s more reasonable to put the fixed arm on the maintenance rack, and the maintenance rack will share a part of boom’s self-weight load, that will reduce the impacts of the boom’s self-weight on the swaying rack and rotary rack, and at the same time enhance the complete machine’s anti-turnover ability on Z-axis direction during ro-ro progress.

For this ro-ro scheme, it’s necessary to analyze the safety of maintenance rack. Considering the worst condition that acting force of the inhaul cable between the fixed arm and the swaying rack is 0
N, and maintenance rack bears all the boom’s self-weight load, the analysis results are shown in Figure 1 and Figure 2.

![Figure 1. Stress nephograms of boom and maintenance rack.](image1.png) ![Figure 2. Stress nephograms of maintenance rack.](image2.png)

The material of the maintenance rack is Q345B, which of yield strength is about 345 MPa, makes safety factor 1.3, [2], so the allowable stress of girder of maintenance rack’s major structure is about 265.4 MPa. As is shown in Figure 2, maximum stress appears on supporting component which connects maintenance rack and fixed arm, and the maximum stress is about 210.982 MPa < 265.4 MPa, safety allowance is enough, therefore the maintenance rack structure is safe even when the inhaul cable is flabby and maintenance rack bears all the boom’s self-weight load.

### Safety Analysis of Boom’s Maintenance Rack

When the complete machine moves on the shoreside track, since the tracks are laid based on the requirement of ro-ro progress, the tracks are smooth, and won’t lead to forced deformation of the ship loader and maintenance rack. During ro-ro progress, the ship loader moves in a sternway, namely along with negative Z-axis direction, while boom and maintenance rack are along with positive Z-axis direction, and the fixed arm and maintenance rack are connected. When the ship loader moves to barge along with the approach bridge, on account of structural features of the approach bridge and hysteresis error of adjusting the barge, there will be about 5-10 cm elevation difference between the surface of shoreside track and the surface of tracks on the barge. Maintenance rack connects with the ship loader and connecting rack through hinge pin, and connecting rack is statically indeterminate structure, so when there is elevation difference between the surface of shoreside track and the surface of tracks on the barge, maintenance rack’s attitude will have 2 situations, as is shown below.

#### First Situation

The first situation is that the front trolley is on the barge in the heading direction of the ship loader, while the back trolley is still on shore, so there is elevation difference between the surface of shoreside track and the surface of tracks on the barge, and the ship loader will incline, and connecting rack is statically indeterminate structure, stiffness of the ship loader is larger than the connecting rack, and then connecting rack will deform to adapt to the incline of the ship loader, internal stress will occur in the maintenance rack. When analyzing the model in this situation, relationship between elevation difference and stress of maintenance rack is obtained in Figure 3, and the stress nephograms of the ship loader and maintenance rack when the elevation difference is 60 mm are shown in the Figure 4 and Figure 5.

![Figure 3. Stress nephograms of maintenance rack.](image3.png)  
![Figure 4. Stress nephograms of maintenance rack.](image4.png)  
![Figure 5. Stress nephograms of maintenance rack.](image5.png)

As is shown in Figure 3, stress of maintenance rack increases with the increase of elevation difference between the surface of shoreside track and the surface of tracks on the barge, and the amplification is sort of large. Figure 5 shows that the inclined brace beam is the part with the largest stress of the maintenance rack. When the elevation difference exceeds 70 mm, the maximum stress of maintenance rack surpasses 250 MPa, close to the material’s allowable stress, so it is necessary to
enhance the accuracy of load adjusting and control the barge, and make sure that the elevation
difference is less than 70 mm when using this scheme during ro-ro progress.

![Graph showing the relationship between elevation difference and stress of maintenance rack.](image1)

Figure 3. Relationship between elevation difference and stress of maintenance rack.

![Stress nephograms of ship loader.](image2)
![Stress nephograms of maintenance rack.](image3)

Figure 4. Stress nephograms of ship loader. Figure 5. Stress nephograms of maintenance rack.

![Deformation of inclined brace beam.](image4)

Figure 6. Deformation of inclined brace beam.

In the first voyage, the first ship loader was rolled on by this scheme, situation happened that
elevation difference between the surface of shoreside track and the surface of tracks on the barge is
overlap large, and then the inclined brace beam deformed, shown in Figure6, in conclusion, this scheme
needs to be optimized because of the existence of danger.

**Second Situation**

The second situation is that ship loader is whole on the barge, while the maintenance rack is not,
while connecting rack is statically indeterminate structure, trolley of maintenance rack will be off the
track and hang on in the air, so self-weight load of maintenance rack will act on connecting rack, also the load on the maintenance rack owing to fixed arm’s deformation, as is shown in Figure7.

![Figure 7. Trolley of maintenance rack was off the track.](image)

In this situation, trolley of maintenance rack was under none constraint, and analysis results are shown in Figure8 and Figure9.

![Figure 8. Stress nephograms of ship loader.](image)  ![Figure 9. Stress nephograms of maintenance rack.](image)

Figure8 shows that in this situation, maintenance rack is the part with the largest stress. And Figure9 shows that the inclined brace beam is still the part with the largest stress of the maintenance rack, the maximum stress of maintenance rack surpasses 261.244 MPa, close to the material’s allowable stress (265.4 MPa), so component will be destroyed with a spot of interference.

Theoretical analyses and practices show that the safety of the main structure can’t be guaranteed in this scheme, and ro-ro scheme need to be improved.

**Improvement Methods**

Theoretical analyses and practices show that the safety of the main structure can’t be guaranteed in this scheme. And in the second situation, the maximum stress of maintenance rack surpasses 261.244 MPa, if maintenance rack is not connected to the fixed arm, and doesn’t bear the self-weight load of boom, the stress of maintenance rack will be small. Even though, the first situation still exists during ro-ro process, and maintenance rack is not safe. Connecting rack is statically indeterminate structure, in order to avoid deformation, it’s necessary to release degree of freedom of connecting rack to balance the deformation.

Two kinds of methods are considered. The first method is that releasing a set of pin which connects connecting rack and the ship loader, namely releasing a rotational degree of freedom. Main structure of maintenance rack weighs tens of tons, large inertial load comes into being when disturbance exists, and then connecting rack deforms a lot, many components are damaged around free end after releasing degree of freedom. The second plan is that taking off trolley of maintenance rack before it moving forward during ro-ro process, as is shown in Figure10.
In this situation lower part of maintenance rack’s main structure is free end, and there is enough distance from track, that helps avoid deformation of maintenance rack caused by elevation difference during ro-ro process, in this moment maintenance rack only bears its self-weight load, and analysis results are shown in Figure11 and Figure12.

As is shown in Figure11, comparing to the ro-ro scheme in the above section, complete machine is uniformly forced in the scheme that taking off trolley of maintenance rack, and the decrease of maximum stress of complete machine is remarkable. Figure12 shows that when using this method, the inclined brace beam is still the part with the largest stress of the maintenance rack, but the maximum stress of maintenance rack is just 62.687 MPa, far less than the material’s allowable stress, that means that maintenance rack can bear its self-weight load. In conclusion, this scheme is easy to implement, and the ship loader is safe during ro-ro process.

Summary

(1) Static analysis on the maintenance rack was carried out by using software ANSYS, and maintenance rack beard all the boom’s self-weight load, the maintenance rack structure was safe.

(2) By analyzing the attitude of the maintenance rack, conclusion came out that in both situation, the ship loader is not safe.

(3) New methods were carried out, after verifying, the result showed that new scheme could guarantee the safety of ship loader during ro-ro process.

References
