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DYNAMICS RESPONSE SIMULATION AND STUDY OF THE SHORE CONTAINER CRANES IN AN EARTHQUAKE

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ABSTRACT

In this paper, shore container cranes are simulated and studied under seismic wave excitation. In ADAMS environment, multi-body dynamics model of shore container crane is established. The real seismic experimental data are imported into ADAMS, which are added to the shore container crane by three directions of X, Y, Z. The rising height of the four door legs and the support reaction force of four door legs under the effect of seismic wave are calculated. Simulation results demonstrate that there is no possible for the shore container cranes to overturn under this type of seismic wave. In this paper, a new method is proposed to study the overturning problem of the shore container cranes system in the earthquake. The simulation results are included to provide a useful reference for the study of the quay crane under seismic wave.

Keywords: Shore container cranes, Dynamics, Earthquake, Rigid multi-body dynamics.

1. INTRODUCTION

In recent years, earthquakes which have brought a great loss of lives and properties to many countries occur frequently. This situation also exacerbates the urgency of seismic design study. Many important ports and terminals in the world are on earthquake-prone zones and the shore container cranes (quay cranes) located on those ports are not only the basis for ensuring the rapid development of port trade, but also the logistics lifeline for large transport of relief supplies to places hit by natural disasters. Currently, there have been lots of research in seismic design for large-scale structures and the focus is mainly paid on buildings and bridges while researches for seismic design on container cranes are still relatively insufficient.

The key issue for seismic design theory is how to improve the seismic capacity of the structure and avoid damage and the collapse of the structure. So far the development of seismic design theory has gone through four stages which are static theory [1-2], response spectrum theory [3-5], the power theory [6-7] and theoretical performance based design [8-13].

In this paper, a multi-body dynamics model of shore container crane is established based on multi-body dynamics software ADAMS. A real earthquake wave is imported into the dynamics model. The dynamic response of the crane under a real seismic wave excitation is calculated to provide a theoretical basis for seismic design.

2. MODEL BUILDING

The global Cartesian coordinate system is utilized in this analysis. Along the direction of the boom to the girder is the positive direction of x axis, the positive direction of y-axis is upright and the positive direction of z-axis is perpendicular to the xy plane. The original point is located on the midpoint of the landside close to the two door legs.

Firstly, a model is established in Solidworks and imported into ADAMS. And then, the related properties are given to the components according to the actual mass and the position of the centroid of each components, which is shown in Table 1.

Table 1. Related properties of the Components

name	weight (t)	Focus X (m)	Focus Z (m)	Height Y (m)
frame	595	15.04		33.88
girder	145	-3.36		56.8
forestay	37.26	55.74		72.
inner backstay	24	13.5		71.39
machinery house	210	-8.58	0.11	60.78
gantry	180	15.24	0	1.5
boom (total)	241	65.43		60.21
WS APEX	47	28.28		79.8

When the model is imported, the lift height of the legs for the rigid body is analyzed. In order to make the analysis simple and directed, the bridge crane is integrated into one model by Boolean operation. The integrated model is reserved by the information of mass, centroid and rotary inertia ect. A wheel is established at the bottom of each leg (wheel 1 to 4), and a component is also built to simulate the ground. A stopper block (stopper 1 to 4) is set in front of each wheel to limit the movement in X direction of the crane. The relationship between the four wheels and the crane is revolute joint. The relationship between wheels and the ground is contact. The stopper blocks are fixed on the ground which is fix joint. The relationship between the stopper blocks and the wheel are contact. The detailed restraint relationships are shown in Table 2. Between the four wheels and stopper block. Specific constraints in Table 2 below.

Table 2. Constraints

Connection object 1	Connection object 2	Constraints	Quantity
Sea Side left leg	Wheel 1	Revolute joint	1
Sea Side right leg	Wheel 2	Revolute joint	1
Land Side left leg	Wheel 3	Revolute joint	1
Land Side right leg	Wheel 4	Revolute joint	1
Stopper block1-4	Earth	Fix joint	4
Stopper block1	Wheel 1	Contact	1
Stopper block2	Wheel 2	Contact	1
Stopper block3	Wheel 3	Contact	1
Stopper block4	Wheel 4	Contact	1
Wheel1-4	Earth	Contact	4

The established model is shown in Fig 1.

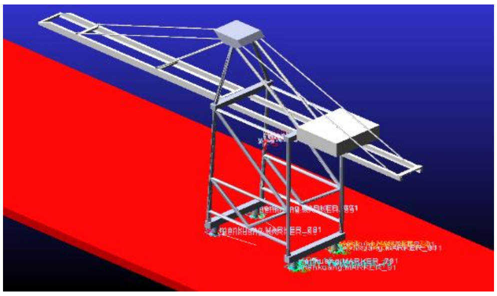

Figure 1. Dynamic Model of Quayside Seismic System for the crane

3. EXTERNAL EXCITATION

The external excitation calculated in this paper is mainly about the seismic wave in X, Y, Z direction. The real seismic experimental data is imported into ADAMS by utilizing AKISPL function (TIME, 0, SPLINE_x, 0) to obtain spline. The excitation forces on the centroid of the crane with seismic wave in X, Y, Z directions are shown as follows respectively:

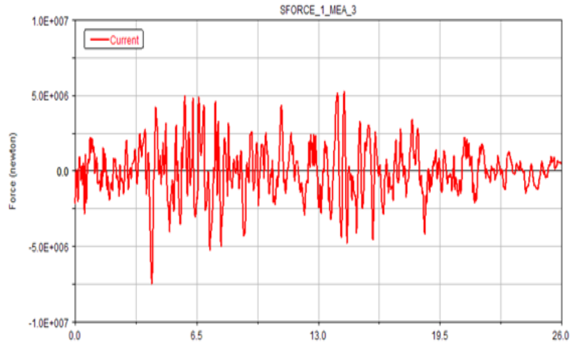

Figure 2. X direction

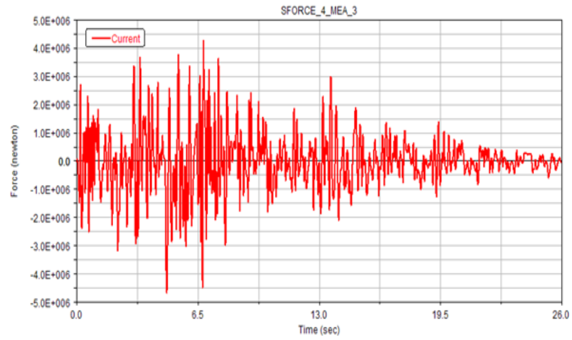

Figure 3. Y direction

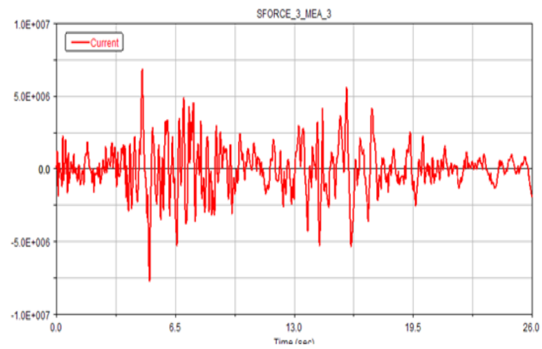

Figure 4. Z direction

4. RESULTS

4.1 The lift height of the gate leg

The results are as follows:

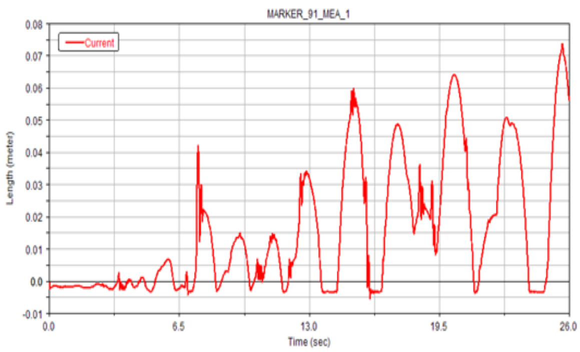

Figure 5. Lift height of land side 1 leg(M)

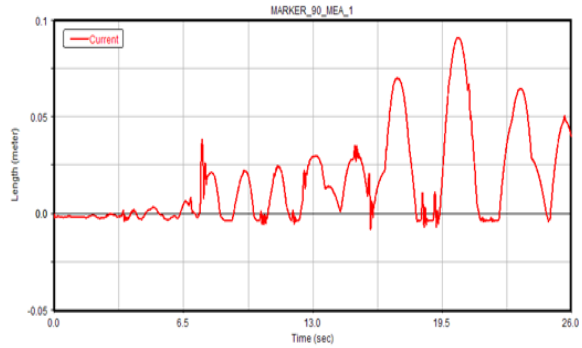

Figure 6. Lift height of land side 2 leg(M)

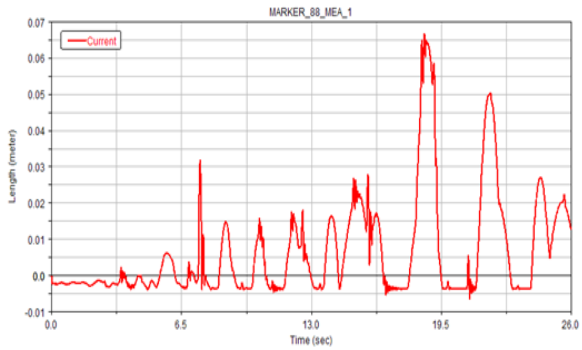

Figure 7. Lift height of sea side 1 leg(M)

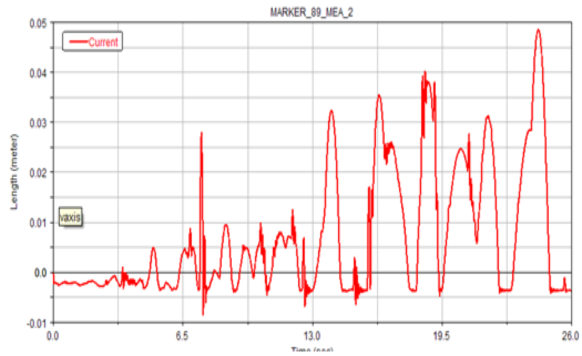

Figure 8. Lift height of sea side 2 leg(M)

4.2 Reaction forces of ground and the gate leg(direction of gravity)

The reaction forces of the four legs (direction of gravity) are calculated as follows:

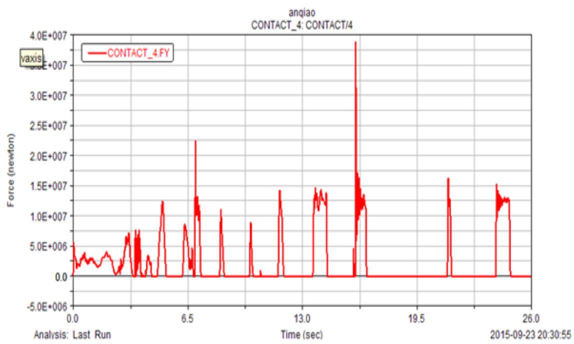

Figure 9. Reaction force of Land side 1 leg(N)

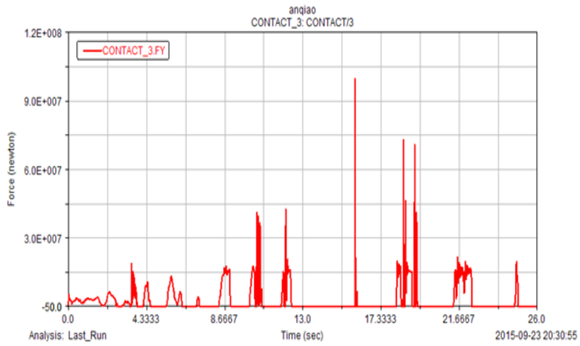

Figure 10. Reaction force of Land side 1 leg(N)

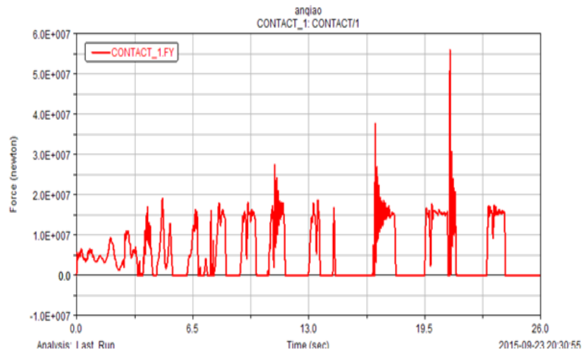

Figure 11. Reaction force of Sea side 1 leg(N)

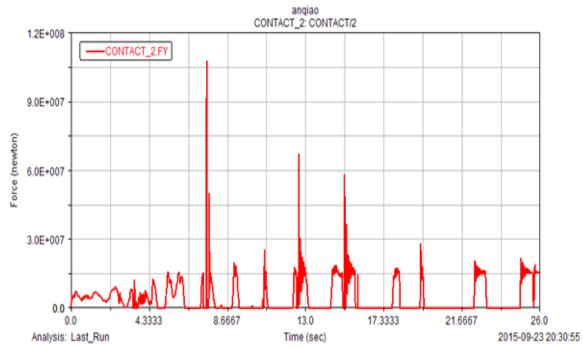

Figure 12. Reaction force of Sea side 2 leg(N)

5. CONCLUSIONS

The rigid body dynamic model is established in ADAMS. The real seismic wave excitation is imported into the model to simulate and calculate. The result shows that the maximum lift height of the crane is 91mm which will not cause overturning.

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