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STUDYING DYNAMIC EFFECTS ON CRAWLER CRANES FOR THE CASE OF ROTATIONAL MOTION USING SIMULATION APPLICATIONS

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ABSTRACT

Crawler cranes belong to the family of mobile cranes that have complex structure with big dimensions and mechanisms and high security requests. Main cycles of the work of Crawler Cranes can be divided into: lifting and lowering the working load, boom lifting and lowering, rotation (slewing) around its vertical axes in 360°, and translational movement forward/backwards. In this workshop, we are going to simulate the work of crawler crane while rotating around its vertical axes when fully engaged with load, which hangs in some height. The aim is to see the effects of dynamic forces (or moments) in the crane's construction during this work cycle, particularly at the start and end of the rotation when working load swings. Reasons for doing this study are occasions of crane instability, while the crane rotates and load swings. We will research the effects of angular speed and workload swaying (swinging) in overall stability of crawler crane by looking for results of swaying angles, dynamic momentums and tensions in cables. By using the modeling applications and applying simulations [3], we are confident that we will have better view of occasions in case of crane rotation and some conclusions for enforcing security and design rules in order to avoid instability and overturning. To do this study, we designed a "virtual crawler crane" using model design and simulation applications and applied simulations based on input parameters and dimensions.

Keywords: Crawler crane, dynamic, rotation, slewing, torque, swaying, cables, tension, simulation.

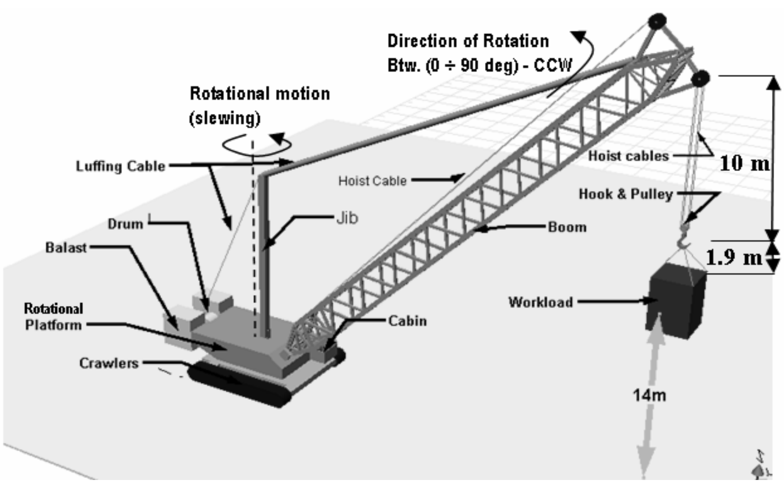
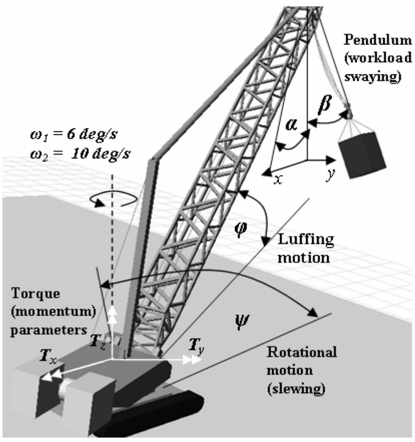


Figure 1. Virtual model of the crawler crane with key elements

1. CRANE PROPERTIES

Properties of the crawler crane: Length of the Boom - 42 m. Mass of the boom – 100 t. Mass of the platform with tracks – 100 t. Max carrying weight Q_{max} = 27 t = 27000 kg.

Crane will be studied for the case of rotational motion (slewing) while the workload hangs in constant height. Rotation will be studied for two cases of angular speed ω = 6 and 10 deg/s when the position (angle) of boom with horizontal is φ = 45º. Work load has the mass equal to max carrying weight: Q = 27 t. Position of the load above the ground is 14 m. Distance from the load and Hook is 1.9 m. Distance from the pulley and boom top is 10 m. Crane will be studied to find the effects of slewing in the crane's construction when fully engaged, by analyzing the dynamic momentum in the platform, dynamic response of load swinging and tension in cables [1]. Below is shown crane with key parameters.



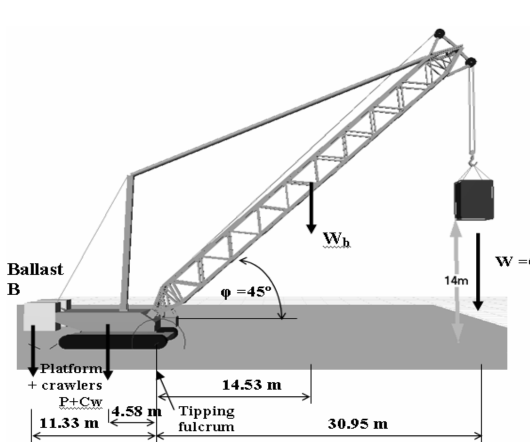


Figure 2. Crane simulation parameters *Figure 3. Crane dimensional parameters*

2. DYNAMIC RESPONSE OF WORKLOAD

During the rotational motion, workload will show extensive swinging around presumed vertical axes in initial position, shown in Figure 2. Angles *α* and *β* (Figure 2) are parameters that will represent the displacement of workload which is important indicator for overall dynamic response of crane. Simulation was carried out for two cases of angular speed, ω_1 = 6 deg/s and ω_2 = 10 deg/s. In diagrams, figure 4, are given the results of simulation.

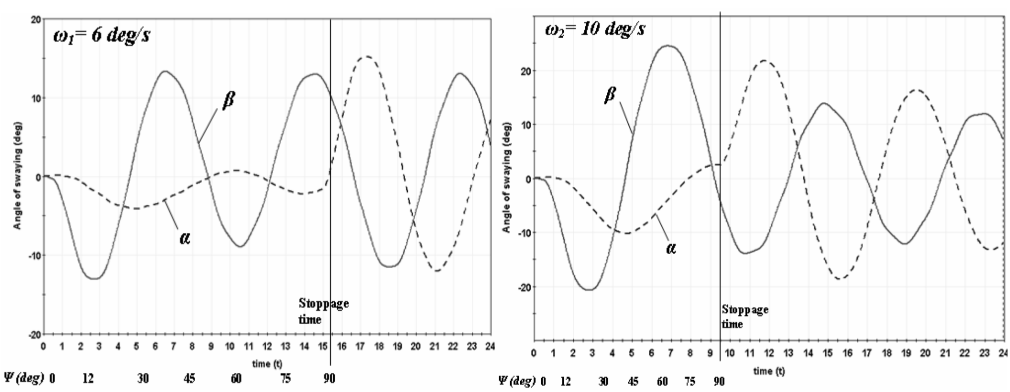


Figure 4. Angles α and β of workload's swaying around vertical axes

In Figure 4, dotted curve represents angle α and full line curve represents angle β. Horizontal axes represents time, also slewing angle ψ in deg. Between time $0<t<0.5$ s, crane is in position of relative rest. At time t=0.5 s rotation starts. This continues until crane rotates for 90 deg. Then it stops rotating. In the graphs, this is *stoppage time,* in the position t=15.5 s for ω_1 = 6 deg/s and t=9.5 s for ω_2 = 10 deg/s. Simulation continues until time t=24 s in order to have a view of after stoppage effects. Diagrams show differences in angles of workload swinging for different angular speeds. For the case of ω_1 = 6 deg/s, max swinging is β = 14 deg, and for ω_2 = 10 deg/s, max swinging is β = 25 deg which is an increase of 78 %. After many simulations, conclusion is that rotations of 10 deg/s and higher could endanger the stability of crane, and rotations lower than 6 deg/s are slow for efficient work. After many simulations, we concluded that best angular speeds are at 8 deg/s. Noticeable are differences between angles α and β. Angle β gives higher amplitudes during motion. After stoppage time both angles tend to equalize, which means that workload makes sort of circular swinging.

3. DYNAMIC MOMENTUM IN THE ROTATIONAL PLATFORM

Dynamic momentum represents the torque on the rotational platform, precisely in rotating gears during the slewing process. As shown in Fig.2, it has three components towards axes of coordinate system T_x , T_y , T_z [2]. We consider that studying this parameter is important for overall dynamic response. Simulation – rotation will be carried same as in paragraph 2.

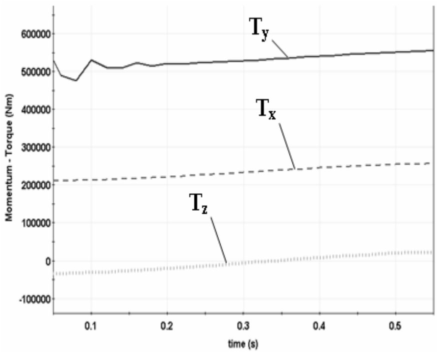


Figure 5. Close to static torque - no rotation

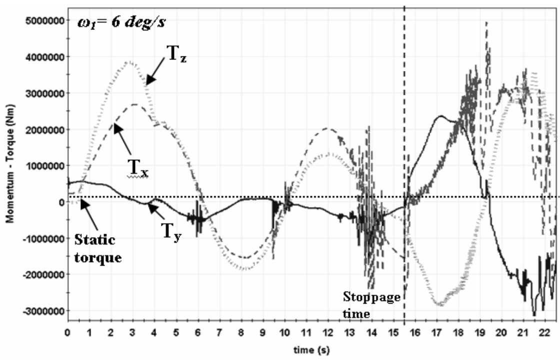


Figure 6. Torque – with rotation at ω_1 = 6 deg/s

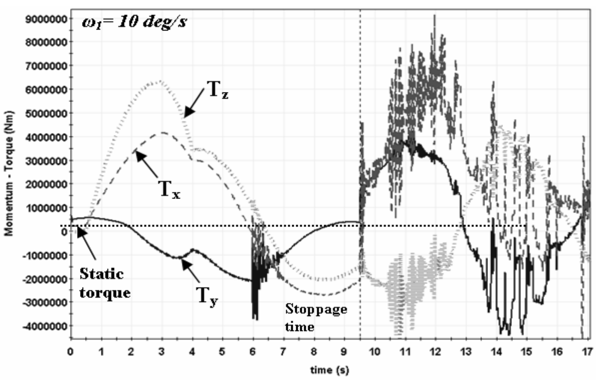


Figure 7. Torque – with rotation at ω_2 = 10 deg/s

On the Fig. 5 is shown the diagram of torque values for the case of no rotation, at the beginning of simulation 0 s < t< 0.5 s, when crane is in the condition of relative rest with some mild workload swings. Figure 6 shows the torque for the case of ω_1 = 6 deg/s. Compared with Fig.5, we see heavy dynamic process of oscillations with high amplitudes and high values of torque. Fig. 7 shows the torque values for ω_2 = 10 deg/s. In this graph, values of torque is even higher than those on Fig.6.

4. TENSION IN LUFFING CABLES

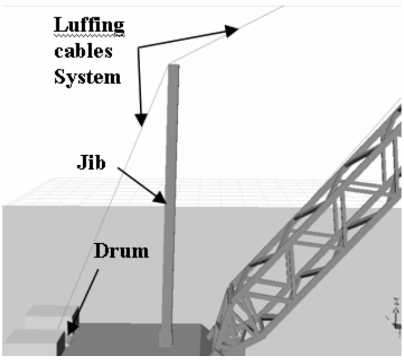


Figure 8. Luffing Cables system

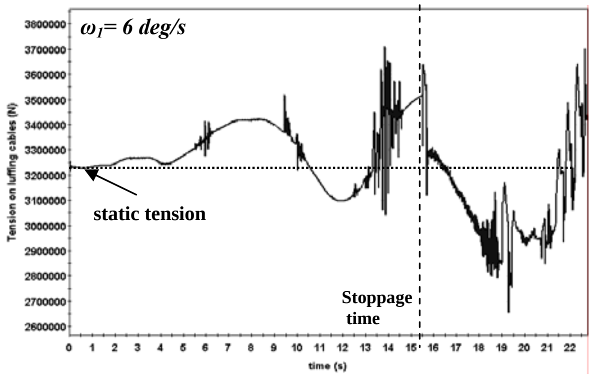


Figure 9. Tension on the cables at ω_1 = 6 deg/s

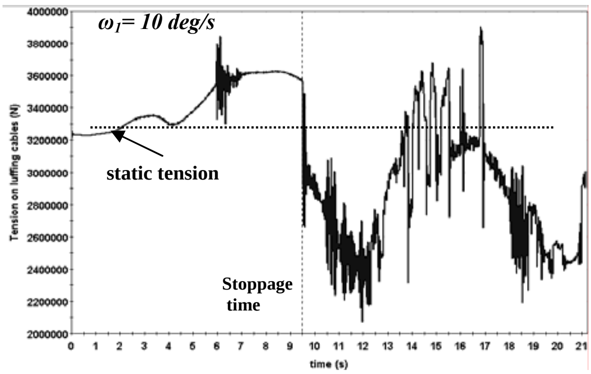


Figure 10. Tension on the cables at ω_1 = 10 deg/s

Tension in the luffing cables is studied for both cases of angular speed. These cables undergo heavy tension (axial force in cables, measured in N) due to swinging of workload [2]. For the case of slewing, cables don't change their length. Figure 7 and 8 are graphs of cables dynamic response for the simulation process. Results are given, compared with static tension. In both graphs, from t= 0 ÷ 0.5 s there is no rotation and values are close to static. Between t = 0.5 and *stoppage time* there is increasing tension with some oscillations. After *stoppage time* results are in a form of sinusoidal curve with heavy oscillations, which are more expressed in Fig.10. This concludes that cables undergo heavy dynamic tension which could damage their structure and duration.

5. CONCLUSIONS

Using modeling and simulations shows very useful to calculate and study the dynamics of crawler cranes. Studying the rotational motion, best known as slewing, proved that this working process is of intense dynamic nature and should not be ignored for calculations. We studied several elements of crane which gave interesting results. In general, angular speeds should be around 7÷9 deg/s, with workload's max swaying angle 18º (for heavy workloads).

6. REFERENCES

[1] Howard I. Shapiro, J.P. Shapiro: Cranes and Derricks, McGraw-Hill, New York, 1999.
[2] Ing. J. Verschoof: Cranes – Design, Practice, and Maintenance, London 2002.
[3] MSC VisualNastran 4D User Guide, MacNeal-Shwendler Corporation, Santa Ana, 2003.