11th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2007, Hammamet, Tunisia, 05-09 September 2007.

STUDYING INFLUENCE OF THE LOAD HORIZONTAL MOVEMENT IN DYNAMIC BEHAVIOUR OF TOWER CRANES USING FINITE ELEMENTS APPLICATIONS

Dr. Musli Z. Bajraktari
University of Pristina, Faculty of Mechanical Engineering

Dr.Ilir R. Doçi
University of Pristina, Faculty of Mechanical Engineering
Pristina
Kosova

ABSTRACT
In this work paper we will study the dynamic behavior of the tower crane during the horizontal – translational movement of the load hanging in the crane's boom. Using computer simulations of the crane's virtual model, we will study the influentia of this motion in the crane's construction when fully engaged with load. We will try to find how does the load swinging effect the carrying construction, what happens when load stops somewhere in the crane's boom and at the peak point, and how does this effects some main parts of crane. For this case we created virtually a whole Tower Crane using Finite Elements and model design application MSC.VisualNastran [4]. Dimensions are from standard manufacturers and using DIN 44 [1]. The results will give us a better view about the dynamic occurrences caused by the load horizontal movement.

Keywords: Tower crane, carriage, motion, momentum, cables, hook, simulation.

1. CRANE PROPERTIES

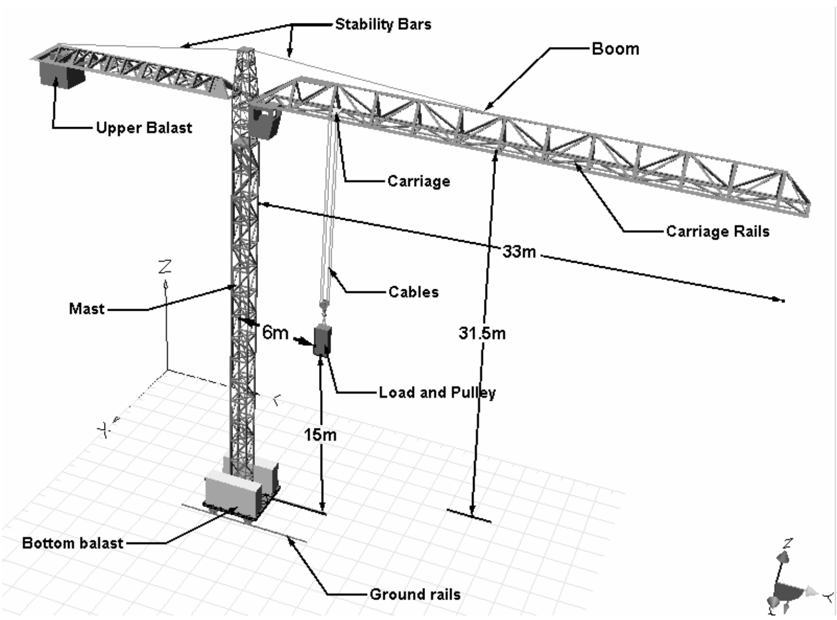


Figure 1. Virtual model of the tower crane with key elements and dimensions

Dimensions of the tower crane: Lifting height – 31.5 m. Length of the Boom – 33 m. Mass of crane with upper ballast, 29.700 kg. Material of crane construction: ANSI Steel; Modulus of elasticity: E=2.1e+11 Pa; Yield Stress: 3.31e+8 Pa.
Weight (work load) is in the position of relative rest at the height of 15 m. The process will be studied for case of work load with mass: Q = 3100 kg = 30411 N. Speed of the carriage is v = 0.5 m/s. Simulation will be horizontal movement of the carriage on the crane's boom.

2. MOMENTUM AROUND MAST

Best parameter for studying this case would be the momentum (torch) around vertical mast (Figure 2). Crane is in position of balance, without application of load. After application of the load, momentum M will appear around the center of the mast. Static momentum for the position (Figure 2) is [2]:

$$M_{st1} = Q \cdot L = 30411 \cdot 6 = 182466 \text{ Nm} \qquad (1)$$

L = 6 (m) – distance of the work load from the center of mast;

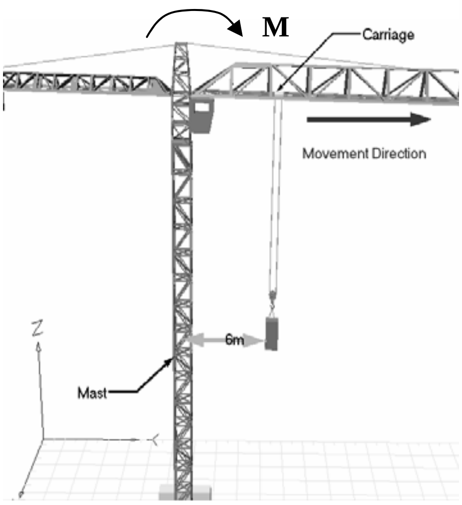


Figure 2. Position of the load

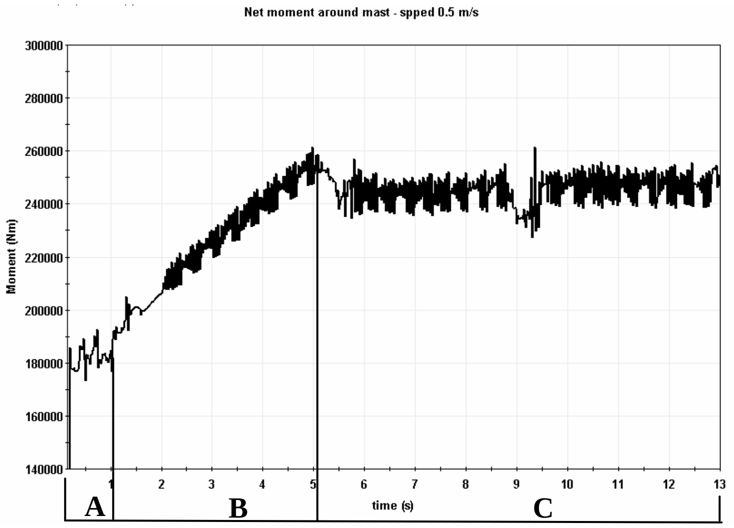
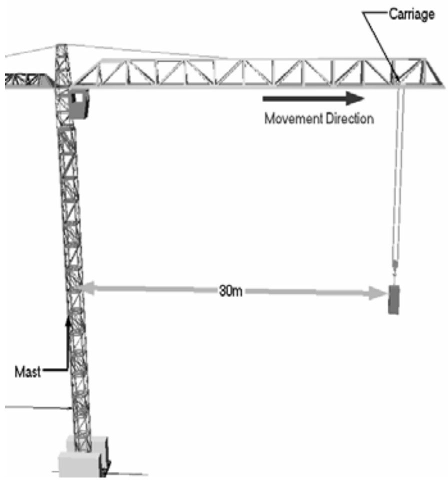


Figure 3. Graphical view of momentum

In the Figure 3 is shown the net momentum around the mast during the process of simulation. Process of simulation is organized in such way that between time 0-1 (s) there will be no motion (A). Then the carriage and load with pulley will move horizontally with the speed of v = 0.5 (m/s) until the time of 5 (s) (2 meters of distance) (B), and then it will be stopped (C). Simulation will be continued until time of 13 (s). This will give us a better view of process. We can see that between time 0-1 (s) (A), load and pulley system are in situation of relative rest hanging on the cables. Value of momentum is around the value of static momentum (1). After the time t = 1 s (B), when carriage and load starts the motion (1s < t < 5s), moment about the mast will increase, while the distance increases. But graph does not show linear increase of moments, but moments with intense oscillations. This dynamic moment appears to be about 10% higher than static moment. After the motion is stopped (t>5 s) the dynamic nature of moment continues in a form of physical pendulum, with intense oscillations.

Next case is for the load position close to the boom's peak (Figure 4). Distance from the center of mast is 30 m. Speed is the same v = 0.5 m/s. Simulation will be same as in previous case. Traveling distance is 2 m. Net moment around the mast is:

$$M_{st2} = Q \cdot L = 30411 \cdot 30 = 912330 \text{ Nm} \qquad (2)$$



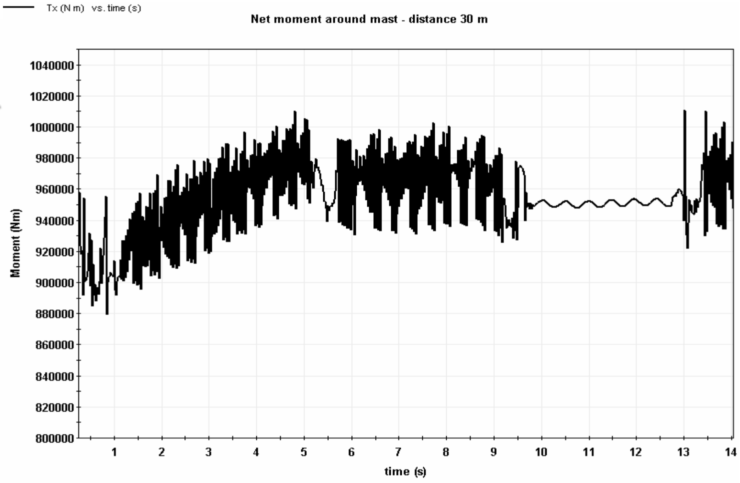


Figure 4. Position of the load close to boom peak *Figure 5. Graphical view of momentum*

Figure 5 gives the graph of momentum. The graph shows no big changes in the form of oscillations compared with the case in Figure 3, but dynamic moment gives some higher amplitudes of oscillations that reach up to 18% higher then static momentum (2). Between time 10 s<t < 13 s, there is some lowering of the swinging amplitudes, but after this, they destabilize.

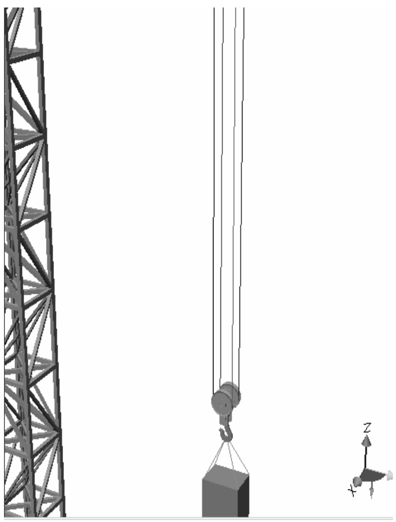
3. FORCE (TENSION) IN LIFTING CABLES

There are 4 branches of lifting cables, on which the load hangs. Maximal load in one cable is [3]:

$$F_{max} = \frac{F_0}{\eta_{ho}} = \frac{7602.75}{0.99} = 7679.5 \ \text{[N]} \qquad (3)$$

Load in one branch of the cable in resting position: Q = 3100 kg = 3100·9,81 N = 30411 N (Mass of load + aprox. mass of lifting devices); η_{ho} = 0.99 - working coefficient of hoist; m = 4 - number of cables.

$$F_0 = \frac{Q}{m} = \frac{30411}{4} = 7602.75 \qquad \text{[N]} \qquad (4)$$



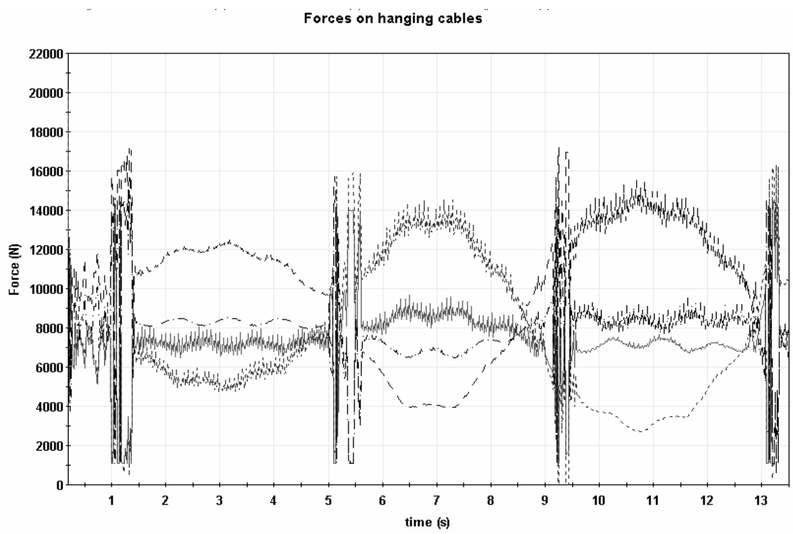


Figure 6. View of lifting cables *Figure 7. Force (tension) in each branch of cables*

Figure 7 shows the graphical view of force acting in lifting cables – all four branches, during this process. Although they vary around the static value of the load in cables (3), the value of force shows high dynamic nature. Between 0<t<1 s, force on cables is around the value of static load (3). This is while weight and cables are hanged freely, with some minor swinging. After startup of the motion 1<t<1.5 s, there is heavy dynamic activity, with high amplitudes of force. Between 1.5 <t< 5 s, oscillations have lower frequency, value of force is not constant and is different for each cable branch and amplitudes of force are lower. When horizontal motion stops (t = 5 s), high dynamic activity appears again. After stoppage time (0<5<13.5 s – end of simulation), graph has periodic changes due to pendulum swinging of the load. Swinging will continue, but it will fade, and around time t = 12.5 min (not shown in graph) cables and load return in the position of relative rest.

4. STRESSES ON THE HOOK

During this simulation process of horizontal movement, we took one element, the Hook, to study the influential on it. The best parameter for results would be the stress (σ_{tot}) on entire element. Figure 9 gives the graphical view of stresses.

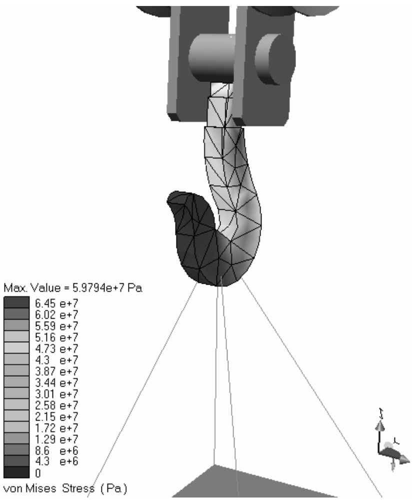


Figure 8. Stress fields on the Hook

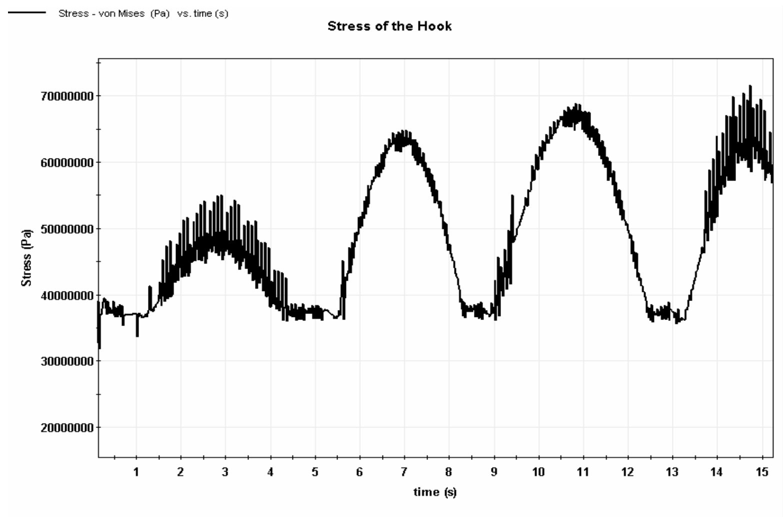


Figure 9. Graphical view of the stresses on the Hook

The curve of stress between 0<t<1 (s)- no motion, is close to the static value of the stress. After the motion starts, in the time frame (1<t<3 s), the value of stress increases with high oscillations, and in the time frame (3<t<5 s – stoppage time) it decreases. Between t ≈ 6 s until t ≈ 15 s (end of simulation), value changes periodically due to pendulum swinging, reaching high values of stress.

5. CONCLUSIONS

Studying the horizontal motion on the crane's boom with work load using modeling and simulations gave interesting results and proved dynamic nature of this process. As every motion process in crane, this process also has its complexity, especially in the moment of motion start and stoppage. It is considered that this process is less complex than other processes, like lifting ex., but, by looking the results, it should not be ignored, and should be considered when planning and constructing cranes.

6. REFERENCES

[1] DIN Taschenbuch 44: Krane und Hebezeuge 1, Beuth, 1995.
[2] Howard I. Shapiro, J.P. Shapiro: Cranes and Dericks, McGraw-Hill, New York, 1999.
[3] Bajraktari, Musli: Mjetet Transportuese, Fakulteti Teknik, Prishtinë, 1986.
[4] MSC VisualNastran 4D User Guide, MacNeal-Shwendler Corporation, Santa Ana, 2003.