12th International Research/Expert Conference
”Trends in the Development of Machinery and Associated Technology”
TMT 2008, Istanbul, Turkey, 26-30 August, 2008

STUDYING DYNAMIC EFFECTS ON CRAWLER CRANES FOR THE CASE OF UP-DOWN MOTION OF THE BOOM USING SIMULATION APPLICATIONS

Musli Bajraktari, ord.prof.
Ilir Doçi, assistant professor
University of Pristina, Faculty of Mechanical Engineering
Pristina
Kosova

ABSTRACT
Crawler cranes are part of mobile cranes family that have complex structure with big dimensions, and high security requests. They work mostly in open environment. Their main role is lifting weight, transporting it to a distance and delivering it in a location which can be in a ground, higher or lower. They can move translational and rotate around its axes. One of main components is the boom, which can move up-down in form of rotational movement. On the boom is the hoist system with cables, ending with hook or some other grabbing device. In this workshop, we are going to simulate the work of crawler crane while lifting-lowering the boom system 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 and stability during this work cycle, particularly at the start and end of the motion. To do this study, we designed "virtual crawler crane" using model design and simulation application Visual Nastran [3], and did simulations. Crane is designed based on manuals of standard manufacturers.

Keywords: crane, dynamic, stability, boom, lifting, lowering, cables, tension, simulations.

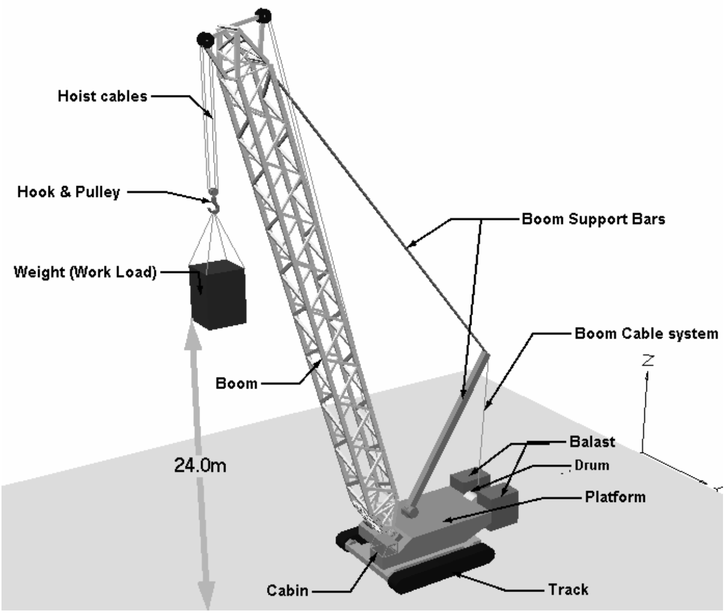


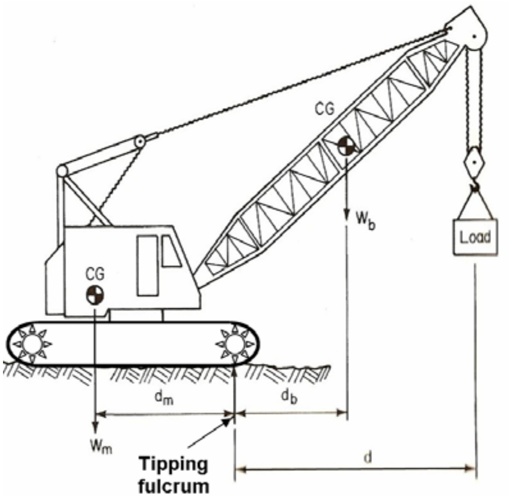
Figure.1. Virtual model of the crawler crane

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 to find tipping fulcrum and stabilizing moment using simulations, and for two cases of boom motion: lowering the boom and lifting it, between the angle with horizontal 25º and 75º. The process will be studied for the case of work load with mass equal to max carrying weight: W = Q = 27 t.

2. STABILITY AGAINST OVERTURNING – STATIC VS DYNAMIC STABILITY

2.1. Static Stability



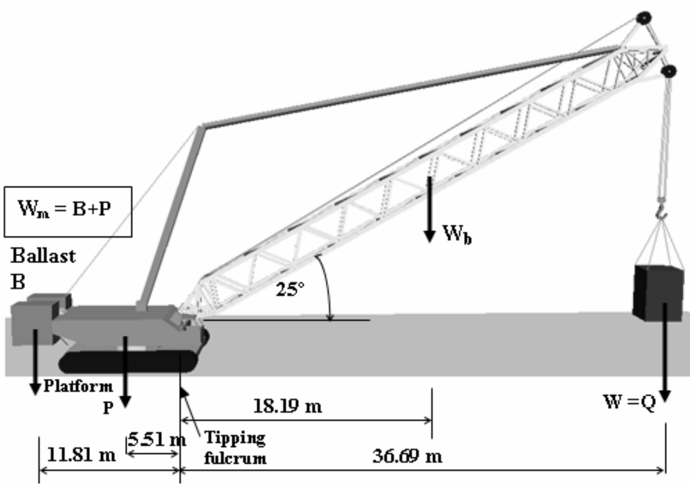


Figure 2. *Figure 3. Crane's loads and distances*

Crane shown in Figure 2 can be made to overturn if a large enough load is boomed out at a great enough radius. Tipping will take place about a definite line called *tipping fulcrum*. W_m is called *machine weight*. Moment of the machine weight about the tipping fulcrum can be expressed as $W_m \cdot d_m$; it is called the *machine resisting moment* or *stabilizing moment*. The moment of the load and the boom given by $W_b \cdot d_b + W \cdot d$, is called the *overturning moment*. The load that produces incipient overturning is the *tipping load* [1]. For our case, as in Figure 3, crane is in position of relative rest, theoretically to static condition; boom is at the lowest most position with an angle of 25º with horizontal, which is considered the *tipping position* of stability [2].

Values of known parameters, from Figure 3 are: Platform P = 100000 kg = 981000 N; Boom W_b = 100000 kg = 981000 N; Working Load W = Q = 27000 kg = 264870 N.

It is very important to find *tipping fulcrum* of the crane, and that can be difficult. Applying simulations, by giving different values for the *stabilizing moment* (different values for ballast B) we looked for the value when crane starts to lose stability. We were able to find the *stabilizing moment* and *tipping fulcrum*. Exact value of the weight of Ballast is B = 189600 kg = 1861026 N and the exact position of the *tipping fulcrum* is shown on Figure 4, with distances from center of gravity of ballast (CGB) and platform (CGP). Values of the moments are:

Overturning moment: $M_o = W_b \cdot 18.19 + W \cdot 36.69 = 27384026 \text{ Nm} \approx 27384 \text{ kNm}.$ (1)

Stabilizing moment: $M_s = P \cdot 5.51 + B \cdot 11.81 = 981000 \cdot 5.51 + 1861026 \cdot 11.81 \approx 27384 \text{ kNm}$ (2)

2.2. Dynamic Stability

With Dynamic Stability we will consider the stability while the crane is working. For our case it's when the boom goes down and up. After simulations, we concluded that the case of boom going down is more interesting for stability study.

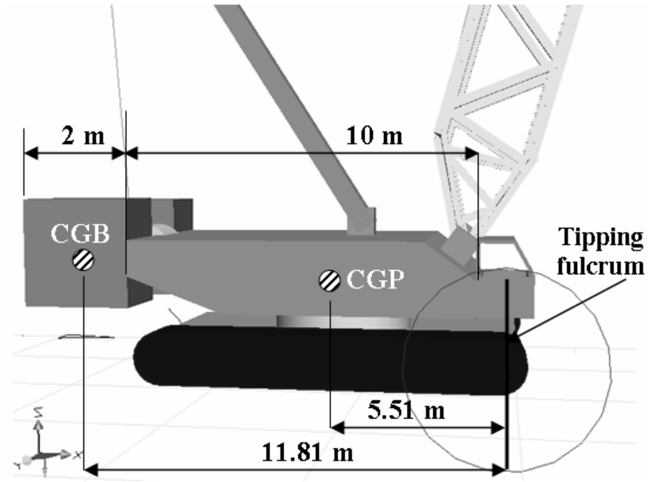


Figure 4. Position of the tipping fulcrum

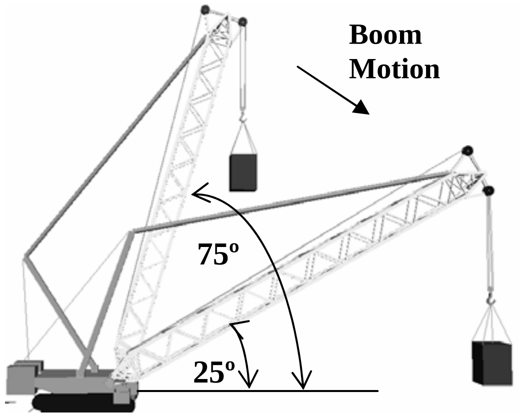


Figure 5. Boom lowering: start - end positions

Work load W is in the position of relative rest at the height of 24 m, with boom angle 75º with horizontal (Figure 5). Simulation will be carried, boom will be lowered (go down) until it reaches the *tipping position* - 25º with horizontal. Speed of the boom lowering will be v_b = 140 m/min.

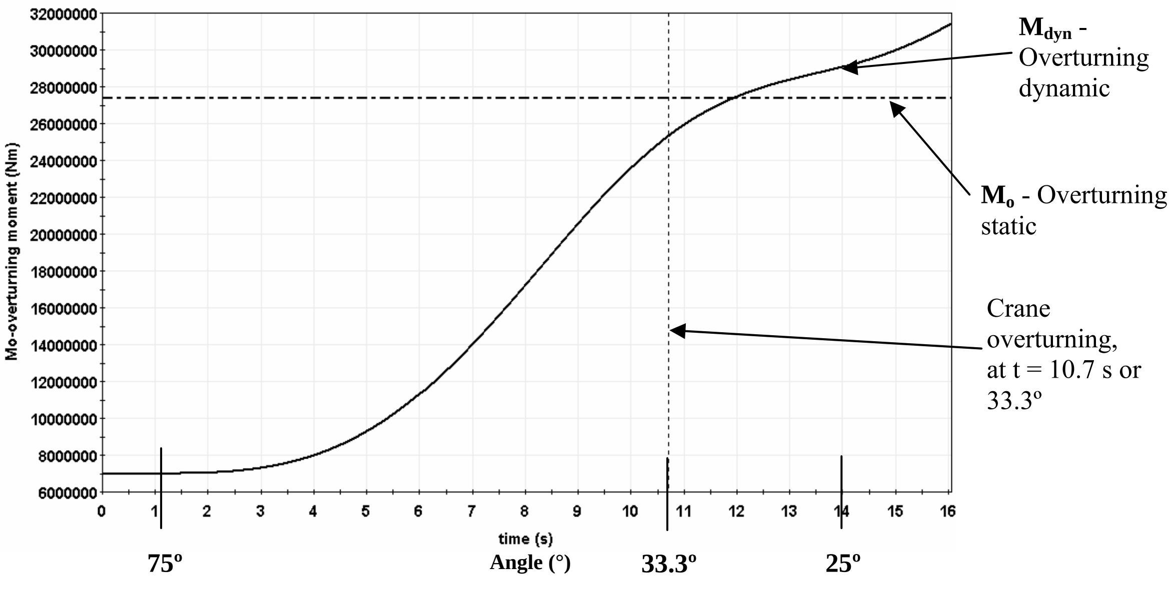


Figure 6.Overturning moment for the case of boom lowering

Graph of Figure 6, shows the values of the overturning moments. M_o – is the static moment from (1), as dotted straight line. Dynamic moment M_{dyn} is moment as the result of simulation, showed in the graph as full curved line. Simulation has been carried for 16 s. Between time 0÷1 s, boom doesn't move. After t = 1 s, boom starts to move down. At the time t = 14 s, boom reaches its lowest point at 25º where it is stopped. Simulation has been continued after boom stoppage, until t = 16 s. Results are surprising! Although the values of the W_b and W are the same as in (1), dynamic moment is causing the crane to overturn, at the forward direction. Overturn starts even before the value of M_o is reached. At the time of t = 16 s, back side of the crane is about 3.14 m above the surface and advancing to total crash. After these results, we concluded that dynamic moment, mainly caused by work load swinging, is causing overturn, and there is no stability. Using simulations, we looked to find proper *stabilizing moment* for crane's stability. We searched for the value of the ballast weight. After many simulations, we found the ballast weight, B_{dyn} = 216000 kg = 2118960 N. *Stabilizing moment* now has a value M_{sdyn} = 30430228 Nm = 30430 kNm. This is an increase for 11.1 % comparing with static M_s (2).

3. TENSION ON THE LIFTING - LOWERING CABLES SYSTEM

Tension on the cables system (Figure 7) is studied for two cases, lowering the boom and lifting the boom. The simulation process: from t= 0 ÷ 1 s, there is no boom movement; between t = 1 ÷ 14 s boom moves down, on t = 14 s, boom stops at 25º. Same, but inverse motion is for boom lifting.

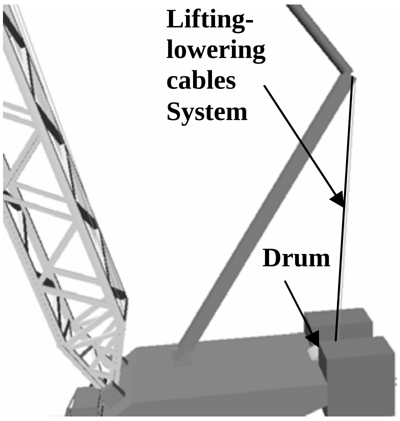


Figure 7. Cables system of the boom

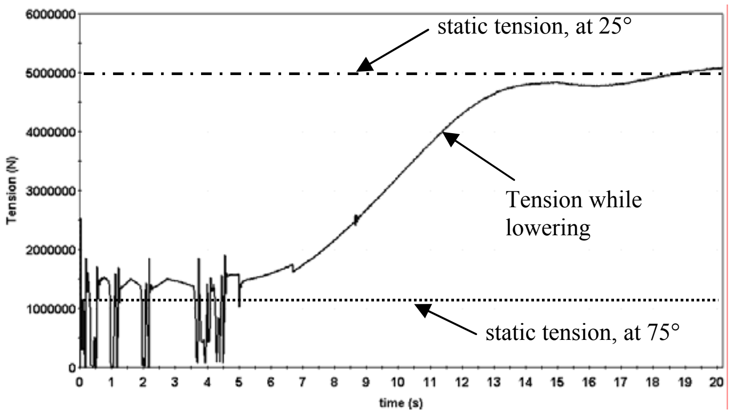


Figure 8. Tension on the cables - boom lowering

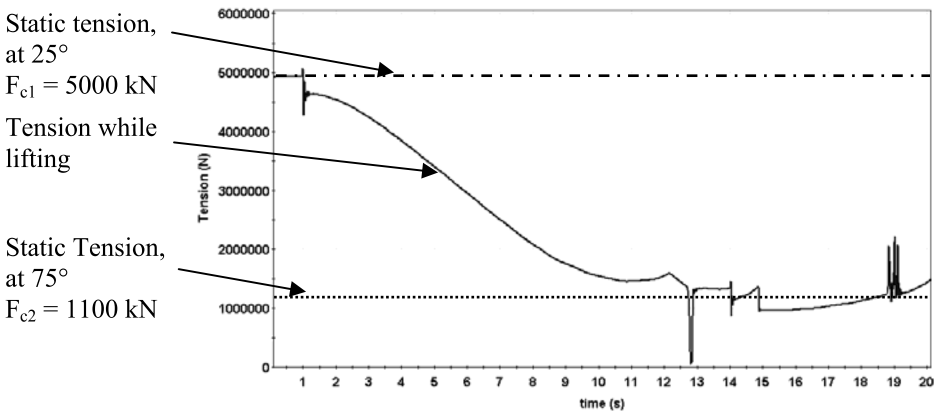


Figure 9. Tension on the cables - boom lifting

Figure 8 gives the tension of the lowering process and shows the difference between static and dynamic values. At the beginning t = 0 ÷ 5 s cables have intense oscillations, after that more stabilizing growing tension, which continues to change even after stoppage time, due to the load swinging. Figure 9 shows the tension on cables for the case of boom lifting up to 75º. Between t = 1 s ÷ 14 s, tension decreases and after t >14 s there are intense oscillations and dynamic process.

4. CONCLUSIONS

Studying the up-down motion of the crawler crane's boom with work load proved the dynamic nature of the process, showed the importance of the dynamic stability and the effects on other parts of the crane. It as a very complex motion process with high importance for crane's stability and safety. Complexity is particularly expressed in the moments of motion start and stoppage. Using modeling and simulations shows very useful to calculate and study the dynamics of these cranes.

5. REFERENCES

[1] Howard I. Shapiro, J.P. Shapiro: Cranes and Derricks, McGraw-Hill, New York, 1999.

[2] Bajraktari, Musli: Mjetet Transportuese, Fakulteti Teknik, Prishtinë, 1986.

[3] MSC VisualNastran 4D User Guide, MacNeal-Shwendler Corporation, Santa Ana, 2003.