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STUDY ON LUFFING MOTION OF BOOM ON CONSTRUCTION CRANES WHILE CARRYING LOAD USING SIMULATIONS

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ABSTRACT
Construction Cranes with Luffing Boom are type of cranes used for load carrying in building sites. They have complex structure with big dimensions and mechanisms, and high security requests. Their working usage is high, sometimes without break during the working times. There are two main types of these cranes: mobile on wheels and static mounted. Main cycles of the work of Luffing Boom cranes are: lifting and lowering the working load, Boom luffing – upwards and downwards, rotation around vertical axes, and (if mobile type) translational movement forward and backwards. In this work, we are going to study the work of this crane while luffing the Boom with full loading- – upwards and downwards. The study will be done using simulations with computer applications. 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 Boom luffing when working load hangs on cables and swings. Main interest is to study the effects in crane's stability [1]. We will search what are the effects of luffing speed, load weight and swinging in different values of Boom's angle. To do this study, we designed a whole "virtual construction crane" using model design and simulation applications, [3]. Crane is modeled from standard manufacturer, [2].

Keywords: Construction Crane, Luffing Boom, Luffing motion, oscillations, modeling, simulations

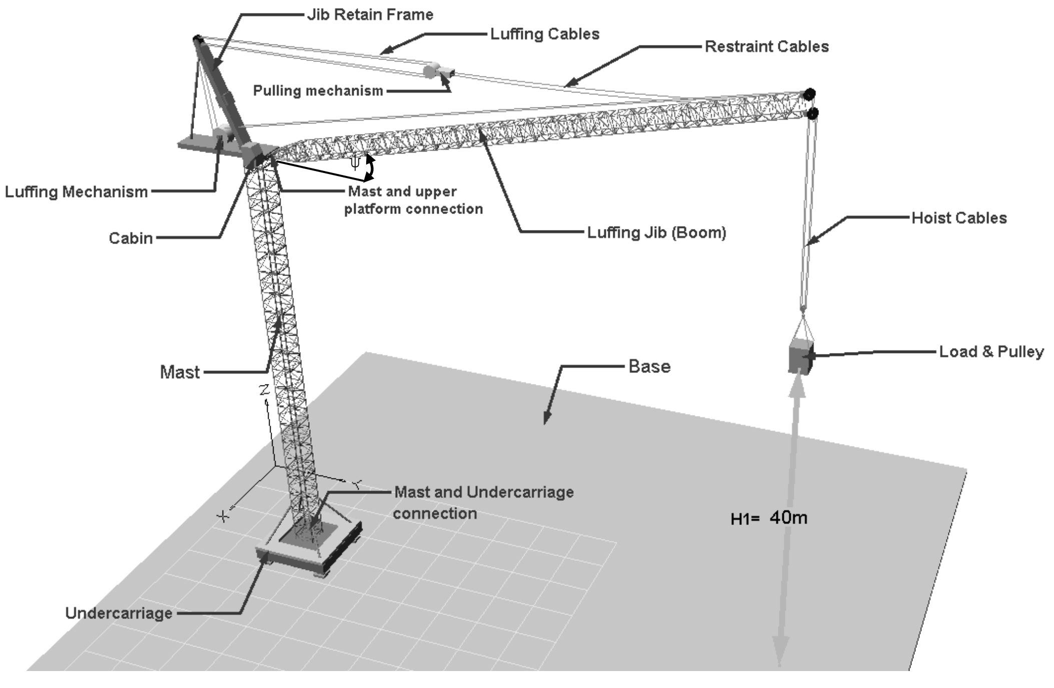

Figure 1. Virtual model of the construction crane with luffing Boom

1. CRANE PROPERTIES AND SIMULATION PARAMETERS

The type of Crane taken for study is Liebherr 540 HC-l2 [2]. Properties of crane are: Length of the Boom - 60 m. Mass of the Boom – 140 t. Length of Mast – 53 m. Mass of mast – 160 t. Max carrying load Q_{max} = 6.6 t = 6600 kg . Boom Luffing angular speed: ω=1.6 deg/s. Boom Luffing can achieve motion between angles ψ =15°÷89°. [2]

Before simulations, weight Q (work load) is in the position of relative rest at the height H1=40 m (Fig.1). Simulation will be done for Boom lifting and lowering (downwards) motion, with angular speed 1.6 deg/s. Simulation has three phases: First phase – initial position of relative rest with no motion, second phase – process of active motion, and third phase - motion stoppage. This form of simulation scenario is close to real work of crane and best for achievement of reliable results.

Upward motion simulation (Lifting) – Boom is in initial position at ψ = 15°. Upward motion will be carried until the position of ψ = 45°, which converts to load lifting of 30 m.

Downward motion simulation (Lowering) – (Opposite to lifting). Boom is in initial position at ψ = 45°. Downward motion will be carried until the position of boom at ψ = 15°, which converts to load lowering until height H1 = 40 m.

2. RESULTS OF FORCE (TENSION) IN LUFFING CABLES

Luffing cables lifts up or lowers the Boom (Fig.1), [2]. They are considered as most loaded part of crane. The result of tension on these cables for both motion cases are shown in the Fig. 2, and Fig. 3.

- *Upwards motion (lifting)* - According to Fig.2, phase one of the process – relative rest of Boom and load is carried between times 0< t <1 s, phase two – process of lifting of boom and load is carried between times 1< t <13 s, and phase three – lifting stoppage, is in time 13 s< t <20 s.

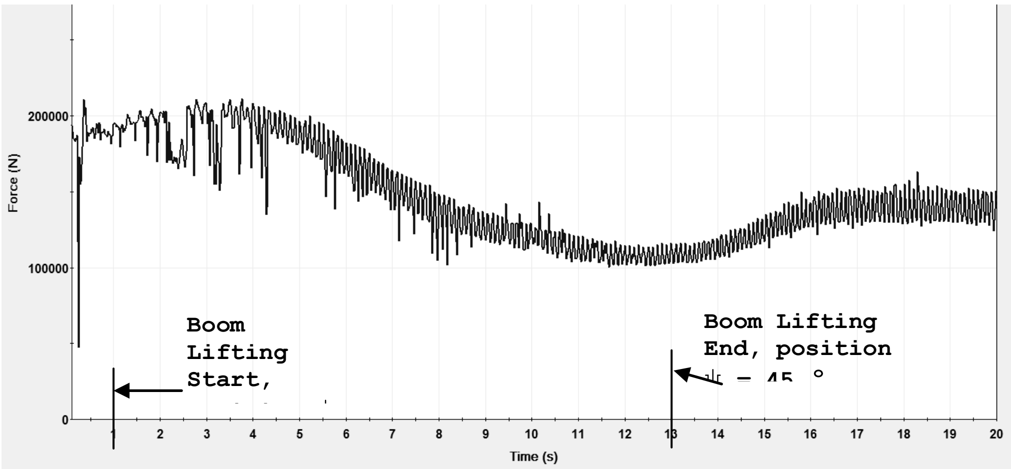

Figure 2. Tension on one of the Luffing cables – during Boom upwards motion.

Based on Fig. 2, lifting is followed by high amplitudes of force-tension in cables at start of process, until t = 4.5 s. After this time, amplitudes are lower, but frequencies of oscillations are high, up to ν = 11 Hz. After t = 13 s when lifting stops, oscillations of cables continue for long time without change in frequencies, mainly due to load swinging. Conclusion is that luffing cables are heavy loaded with oscillations that result in hight amplitudes and high number or freqeuencies.

- *Downwards motion (lowering) – (*Fig.3) - all three phases of motion are in same time frame as in lifting motion, the difference is the Boom and load are moving down. Based on the graph, the curve of force is very different than for lifting. At the start of process, until t ≈ 2 s, there are high amplitudes of force oscillations, but small frequencies. Between 2 s < t <6 s, force increases, with little oscillations. After t > 6s, force oscillates with heavy amplitudes and frequencies up to ν = 12 Hz.

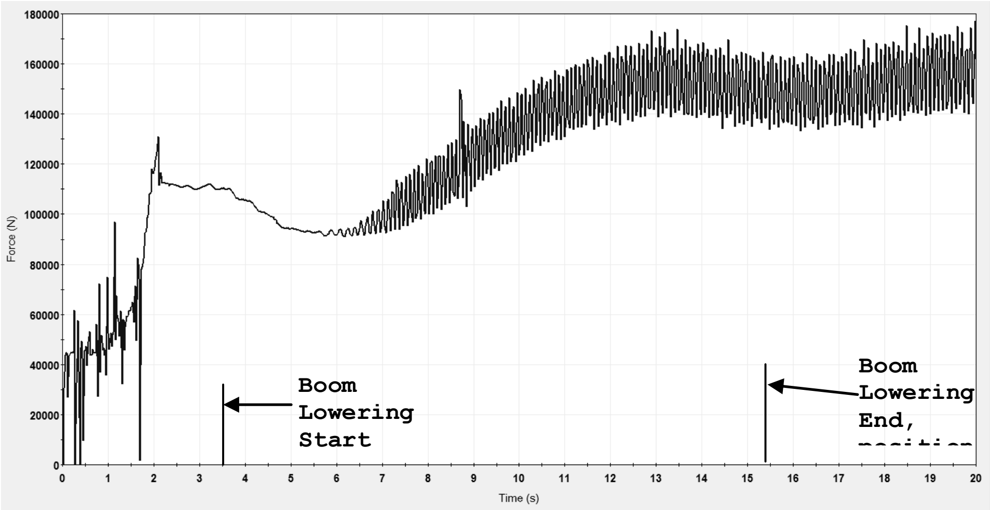

Figure 3. Tension on Luffing cables – during downward motion

3. FORCE IN THE CONNECTION BEETWEN UPPER PLATFORM AND BOOM

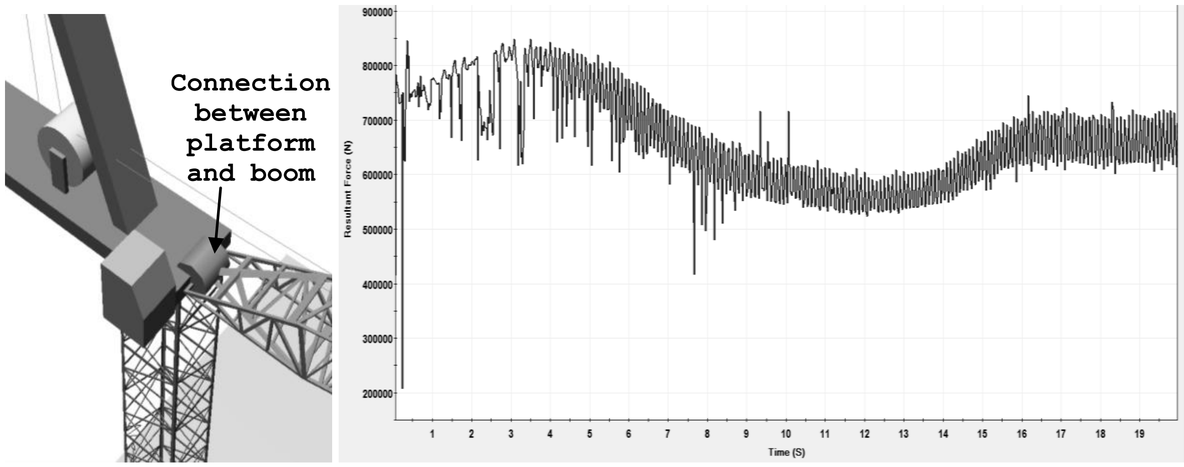

Figure 4. Resultant force in the connection of upper platform and boom during lifting motion

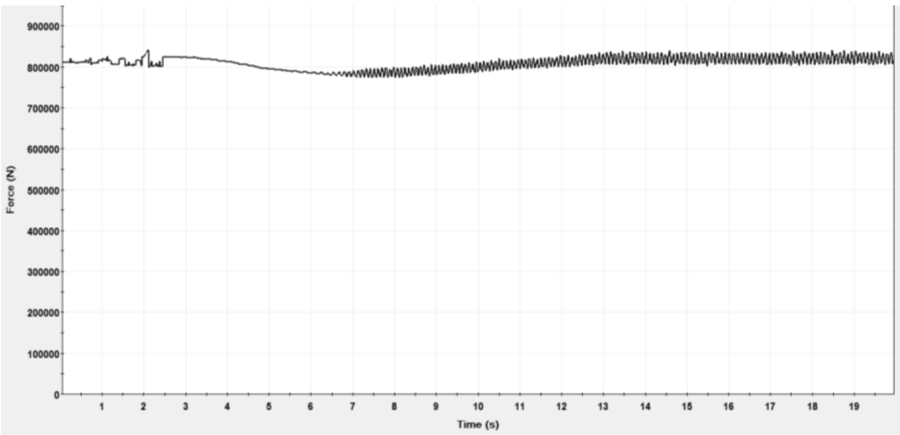

Figure 5. Resultant force in the connection of upper platform and boom during boom lowering

This connection is important part of these cranes for determining dynamic effects. Comparing results from Fig. 4 and Fig. 5, we can conclude that lifting process shows heavier dynamic nature than lowering. Value of max amplitudes based on Fig.4 is: $\lambda = 8.6\text{-}6.1 = 2.5 * 10^5$ N (t ≈3 s), while in Fig.5 is: $\lambda = 8.4\text{-}8.07 = 0.33 * 10^5$ N (at time t ≈ 15 s), which is huge difference of $\Delta\lambda = 2.17 * 10^5$ N.

4. FORCE IN THE CONNECTION OF BOTTOM MAST AND UNDERCARRIAGE

Important parameter for studying is resultant force at the bottom of vertical mast and undercarriage (Fig. 4). Similar to Paragraph 3, comparing Fig.6 and Fig.7, we can conclude that lifting process is more intense in dynamic nature than lowering process. Negative result of lowering is that shows more irregular oscillations in period 2.8< t <5s and t ≈19 s due to load swinging and boom lowering.

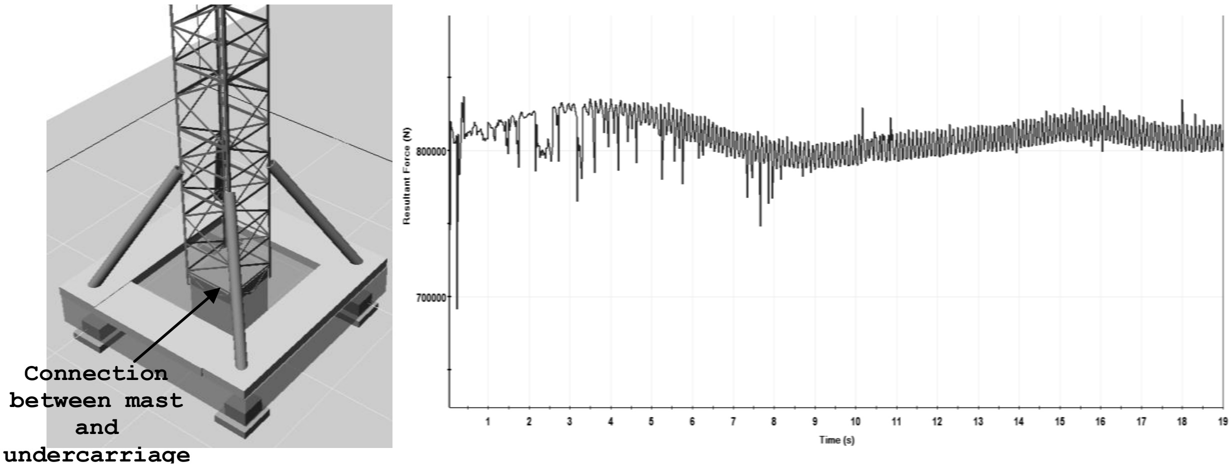

Figure 6. Resultant force in the connection between mast platform and undercarriage during lifting

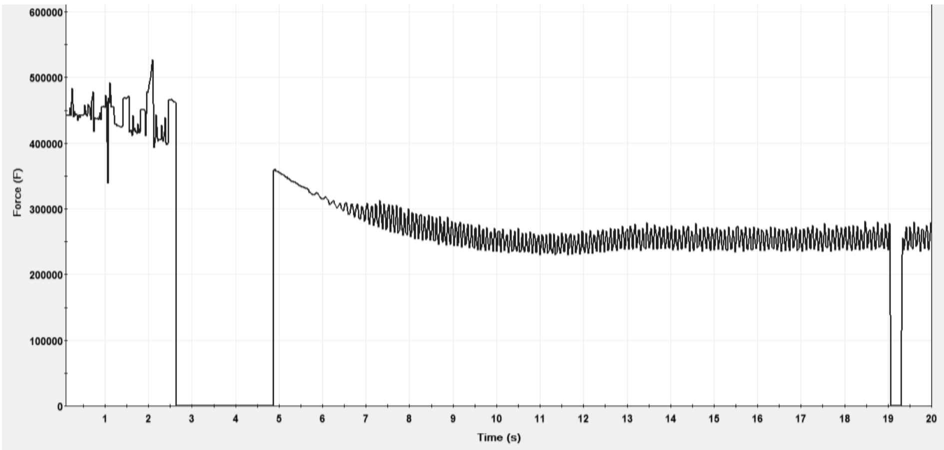

Figure 7. Resultant force in the link between mast and undercarriage during downwards motion

5. CONCLUSIONS

Studying lifting and lowering of load in case of boom luffing motion proved the dynamic nature of the process. Applying simulations with software is a good method to find crane’s acting dynamic forces, and determining dynamic stability. Lifting process is more intense dynamic process than lowering. Main issue in luffing process are oscillations with high frequency and big amplitudes, and mostly with irregular occurrence. Most complex work periods are motion start and stoppage. These oscillations that might be difficult to measure with instruments, can explain causes of parts failure, materials fatigue and stability problems. They are mainly induced by forces acting in cables, boom and by load swinging. Speed of motion is another parameter that needs to be checked.

6. REFERENCES

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