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Calculation of the dynamic behaviour of lattice boom mobile cranes during hoisting motion with a vibration model

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Abstract

Lattice boom mobile cranes are mainly used for moving heavy payloads with a large hoisting radius. They typically allow a hoisting capacity of more than 1000 metric tonnes and a maximum hoisting radius of about 200 meters. Mobile cranes are set up with long and elastic lattice booms and acute angled suspensions. Their fundamental motions are hoisting, slewing and luffing. Due to increasing load capacity, the slender boom system has become more and more complex. During the working process, crane motions cause dynamic forces on the crane's structure. In order to guarantee the safety of cranes, it is essential to do a very exact calculation for the boom system. One main task during calculation is to reflect the system's realistic dynamic behaviour. According to current standards [2-7], stress calculation for mobile cranes is done by using quasi-static approaches. To estimate the dynamic loads the standards stipulate the use of dynamic factors. The factors are often based on the experience of the crane manufacturers or, in alternative, they can be taken from tables in the standards.
There exist several publications that deal with the cranes' dynamic behaviour [8, 9, 13, 17, 18] and the use of dynamic factors in the stress calculation [19]. In some previous works it is shown, that the calculation standards often describe the dynamic effects only approximately for the motions of slewing, luffing and hoisting of a grounded load [1, 9, 10, 13, 14]. For this reason, the standards allow the use of other methods to calculate dynamic effects. One possibility to characterize the dynamic behaviour of cranes in a very accurate way is the use of the nonlinear dynamic finite element calculation. The main disadvantage of this method is the much higher computing time consumption compared to the static calculation. Furthermore, there is no reasonable possibility to take the standards' partial safety factors into consideration. For these two main reasons the dynamic calculation is used very rarely by crane manufacturers, although it allows exact and reliable calculations.
In order to achieve a more exact calculation of the dynamic behaviour of cranes without increasing computing time inappropriately, special vibration models, which are based on the equation of motion of the nonlinear dynamic finite element method, are developed in a current research project. Previous publications have shown that these models can describe the dynamic behaviour precisely for the motions of hoisting a grounded load and slewing of mobile cranes and loader cranes [11, 12, 16]. In this paper a new vibration model for the process of hoisting suspended loads is presented. To avoid increasing computing time, linearized formulations and the method of modal reduction are used in this particular model. One important aspect is that model reflects the dynamic effects in a more accurate way than the methods commonly used by the present standards. For this reason, the use of the new calculation method can improve the crane safety. The described vibration model is based on the response spectrum methodology which is also used in a similar way in the field of civil engineering to calculate the effect of earthquakes on high-rise buildings [15]. The model allows the generation of static loads which describe the maximum dynamic load of mobile cranes in a more exact way than loads based on the European standards. In addition, it is possible to use the safety factors that are stipulated in the standard. The results of the vibration model are compared with the outcome of the nonlinear dynamic finite element calculation. The applicability of the model is shown for a mobile

crane with various set-ups, different loads and different boom positions (see Figure 1). To review the exactness of the model, the comparison takes various accelerations and velocities of the hoisting drive into account. Furthermore, a comparison between the results of the calculation according to the current European standard for mobile cranes [2] and the other methods is emphasized and the advantages of the proposed calculation process are presented.

Keywords: mobile crane, dynamic calculation, finite element method, modal reduction, hoisting motion.

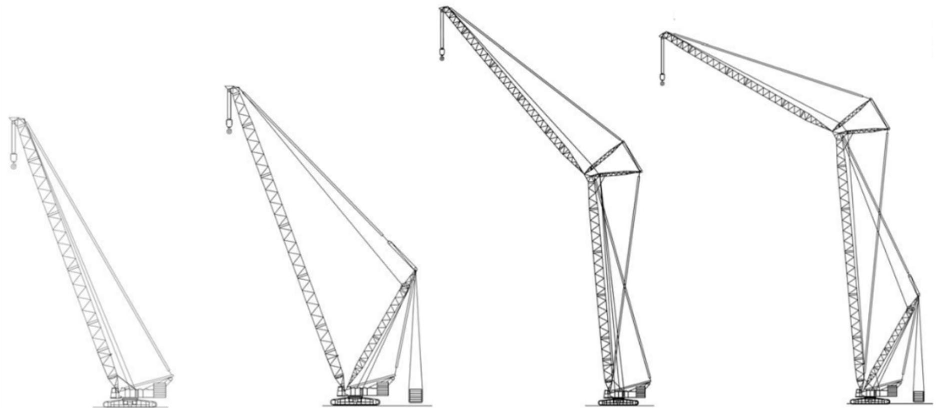

Fig. 1. Analysed mobile crane set-ups [9].

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