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Port Crane Guidance Dynamics Analysed Via the Multibody Approach

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EXTENDED ABSTRACT

1 Context

During the last decade, major transformations in terms of cadence are taking place in ports, therefore the cranes that continually load and unload containers are also being impacted. These developments give rise to problems of a new nature: the behaviour of cranes was considered until now quasi-static or cyclical, but it is becoming progressively dynamic. These associated effects are causing significant damage to the cranes, the track and the foundations. This adversely affects the integrity of the rail guidance system leading to reduced operating performance, system downtime and costly repairs.

The goal of this research is to understand the dynamic effects of the parameters of a crane on track through a research project involving industrial partners. Dynamic effects present new challenges for crane manufacturers, track specialists and operators regarding the increasing loads and operational speeds, the goal is to model the whole system (crane, track, foundation) with an ad hoc multibody simulation, in order to capture the associated dynamic phenomena as precisely as possible, especially at the track level.

2 Model and methods

A complete crane model has been designed using the ROBOTRAN [1] symbolic multibody software. The outcome of this modelling work required gathering a series of data related to the crane's gantry, the rolling elements and the track, in order to feed a global multibody model with the following specific ingredients:

- A wheel/rail contact model definition taking high creepage and high forces into account. It is included in the form of vertical kinematic constraints (perfect wheels on a perfect rail) and tangent frictional forces based on the Kalker non-linear model [2]. To set the idea, the rail gauge, unlike to railway system, is 27,90 m. Moreover, the crane rail system must hold up to 40 tons per wheel.
- A rail alignment irregularities model which inevitably impact the crane's running quality. They are defined as sinusoids with amplitudes and wavelengths adapted to the norm ISO 12488-1.
- The modelling of side rollers (with vertical axes, Figure 1) in intermittent contact with the rail. It is treated, in this first model, as an unilateral spring/dumped system, whose lateral deflection mainly comes from that those of the rail (flexion and torsion) [3].
- Identification of the stiffnesses of the gantry (deflections in the 3 directions and eigen modes). The aim is to calibrate the multibody model on the finite element model (FEM) (continuous flexibilities) provided by the crane manufacturer.
- Motor control definition. Each wheel (see Figure 1) is controlled individually to correct the skewing phenomenon that represents a less than optimal behaviour in which wheel/rail creepages are high and induced undesired wear.

To validate the model, experiments are being carried out in the port via a strategic location of accelerometers and force sensors that are being installed on a test crane in Antwerp, Belgium (Europe). Various crane conditions are investigated: static configurations, lateral and longitudinal trajectories, etc.

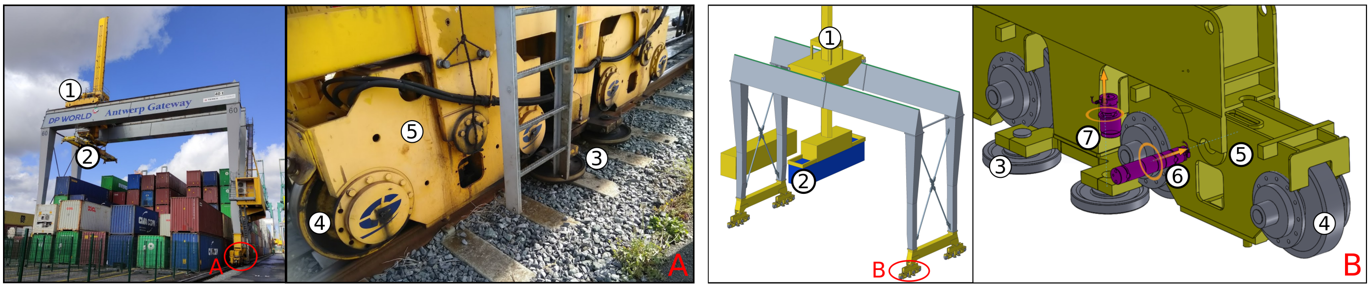

Figure 1: Real ASC model on the left and virtual 3D model on the right. Parts: trolley (1), container placement (2), side rollers (3), wheels (4), bogie (5), vertical force sensor (6) and lateral force sensor (7).

3 Results

Preliminary results from multibody simulations are already able to highlight the impact of several parameters on the crane dynamics. For instance, regarding vertical forces, force sensors are currently being installed in the axles of the bogies (Figure 1, the one on the right). The results on the left side of Figure 2 show that the trolley motion (Figure 1) has a significant effect on these vertical forces for a realistic trajectory of the crane, with a dynamic amplification that largely increases with the default and that is much higher than that currently recommended in the field.

In the port, to take track lateral irregularities into account, simulations with different roller-track plays ("gaps") have been carried out. Significant differences (Figure 2, right) in the roller/rail lateral forces are revealed at the level of the rollers for different play values.

Other simulations show that the addition of irregularities in the rails affects the power dissipated at the level of the side rollers. This fact could be one of the main factors that explain the origin of the wear detected, thus future studies will delve into the analysis of these defects.

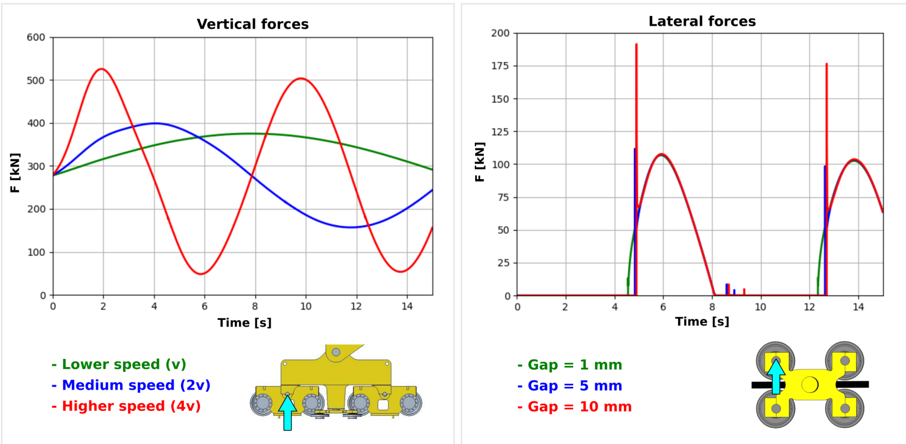

Figure 2: Resulting forces for a crane simulation in which the trolley (Figure 1), that manipulates a load of 40 t (container and holding elements included), moves laterally with a realistic sinusoidal speed. Its value is maximum in the middle of its trajectory and 0 at the ends. Left: the forces produced in the bogies axles are maximum when the trolley is on the same side and these peaks highly increase with the velocity. Right: example of lateral forces on side rollers for different gap roller-track values.

4 Conclusion and perspectives

Crane dynamics impacts operation and should be taken into account in the crane operation and track engineering, especially regarding the guidance issues. The current industrial problems which are generated by the rates highlight the need for a better comprehension of their behaviour. At this point, the multibody simulations of the model have shown to be able to study different realistic scenarios and to measure quantities forces, displacements or contact wear at its different levels (track, wheels, rollers, bogies). This model is being validated on the database obtained from field measurements and it is envisaged to be shown during the conference.

In terms of perspective, the multibody model of the crane will be coupled with the ballasted track conceived with the Discrete Element Method, as we previously did in a scientific paper [4], to finally have a complete model of the crane.

Acknowledgments

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