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Virtual Modeling of Miner Track System

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ABSTRACT

Deep-sea mining system technology is complex, expensive and difficult to develop due to high cost and risks of physical models constructions. The development of deep-sea mining simulation test system is the early concept of design innovation and it is an effective tool to accelerate the maturity of the technology to ensure stable and reliable performance. RecurDyn is fully integrated linear and non-linear FEA capability software which allows the creation of detailed realistic models for design studies and product's performance improvement. In this paper a miner track system was modeled based on an optimized design in order to check for its feasibility.

Introduction

A deep sea miner or sometimes called a seabed crawlers is a remotely-controlled tracked mining vehicles designed to sink to the bottom of the sea in order to collect, crush, gather and send the minerals to the production support vessel. Miners are preferred to be tracked than legged because of the better floatation and the larger traction force required for the mining system stability in extremely weak deep-seabed soils(Sup Hong and Hyung-Woo Kim, 2005). In deep sea bed mining the miner is the key equipment of the whole system that is charge with the most complex and dangerous task (Enno Schulte and W.Schwarz, 2009,Wang et al., 2003). In developing miners of high performance, dynamic behavior should be investigated under various traveling conditions(Jae Jun Jung et al., 2005), thus their trafficability on soft soil will depends strongly on the proper driving resistance.

RecurDyn is an innovative Multibody Dynamics (MBD) based Computer Aided Engineering (CAE) software offering state-of-the-art MBD capabilities with an integrated powerful and unique non-linear Finite Element Method - FEM extension(Wikipedia, 2013). RecurDyn's Finite Element Method combined with its Multi Body Dynamics - MFBD (Multi Flexible Body Dynamics) mechanical system simulation returns more precise dynamic motion results including stress analysis in one single simulation step and also features flexible body contacts and non-linear deformations(Wikipedia, 2013,FunctionSIM, 2013). The unique Recursive Dynamics solver technology represents one of the most efficient ways in solving Multi Body Dynamics equations of motions today, and at the same time providing high-rated solver robustness and reliability. RecurDyn is easy to use because it has been built from the ground up in the Windows environment. This means that functions such as "drag and drop" and "cut and paste" work in the same expected way between applications (FunctionSIM, 2013). RecurDyn has a fully integrated linear and non-linear FEA capability allowing the creation of detailed realistic models for design studies and product's performance improvement. Directly FE meshing in RecurDyn model makes it possible to simulate overall motion as well as local deformations and stresses(Lee et al., 2010,FunctionSIM, 2013). Model building, simulation and post-processing interfaces provide the best design and analysis tool for complex mechanisms. It is also highly robust and stable thus models require much less parameters tuning to produce results(Function Bay, 2005,FunctionSIM, 2013). RecurDyn has the benefits of improved insight in true system performance. It can has a better turn around on simulation project, fast and robust solver enabling true optimization of complex models thus given a faster design analysis and shorter production time (MotionPort, 2013).

The Low-mobility Tracked Vehicle toolkit (see figure 1) focused on tracked equipment with discrete steel shoes, track shoes that are defined as an extruded profile, track with external guides that keep the track shoes from falling off of the rollers, track system with single sprocket that contacts the shoes at their centers (MotionPort, 2013,Function Bay, 2009).

Figure 1. RecurDyn Track LM toolkit

Deep-sea mining system technology is complex, expensive and difficult to develop. Though, it is necessary and important to conduct experiments in problem detection and solution testing, high cost and risks of physical models constructions made it prohibitive in the early stage. Reliance solely on computer simulation analysis and calculation is enough in ensuring reliability. Therefore, the development of deep-sea mining

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simulation test system is the early concept of design innovation and it is an effective tool to accelerate the maturity of the technology to ensure stable and reliable performance. This makes the simulation an important research aspect of deep-sea mining technology.

Since Bekker's pioneering studies (Bekker M.G., 1956) a large number of literatures are found in which experimental and theoretical works on the performance analysis of tracked vehicles for soft soil have been carried out. But so far none of the above works have been specific in analysis and simulation of the only track system only. Although Umaru et al (2012) (Samaila Umaru et al., 2012) analyzed the track but simulation was not considered.

In this paper the simulation of a miner in linear motion and steering (turning) using RecurDyn was presented.

Miner Track Modelling

The Track LM toolkit is used in constructing the miner model in RecurDyn by using just Pull-and-Click interface. The data used for the modeling are given in tables 1 and 2.
The complete miner model is as shown in figure 2

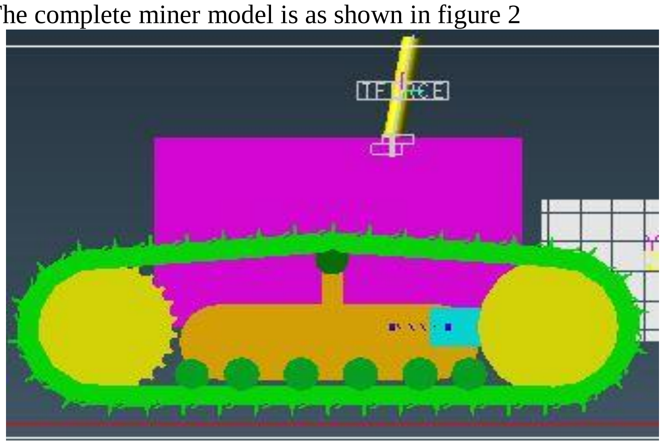

Figure 2. Complete miner model of the System

For the miner track components, the idler is connected to the track tensioning mechanism (tensioner) by a revolute joint. The road-wheels are attached to the track- frame with revolute joints. The carrier roller is attached to the track- frame with a revolute joint. The sprocket is attached to the mother body with a revolute joint, and it has a motion or a torque relative to the mother body. The tensioner is attached to the track-frame with a translational joint and the track-frame is attached to the mother body with fixed joint.
Miner Track system model is as shown in figure 3.

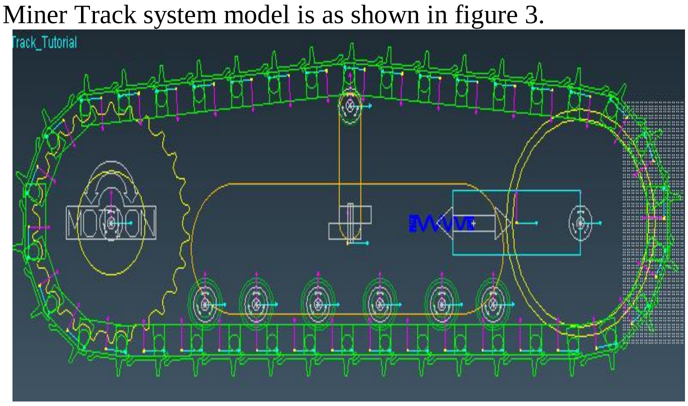

Figure 3. Miner Track System Model

The terrain is defined by using the Road Data and Outline Road toolkit. The ground contact parameters describing the pressure between the ground and the track segment could be selected by adjusting the Track Assembly entity properties using the Characteristics 1 Tab. There are fourteen different ground contact models in RecurDyn: Dry Sand Model, Sand loam (LLL) Model, Sand loam (Michigan) Model, Sand loam (Hanamoto) Model, Clayey Sand Model, Heavy clay Model, Lean clay Model, LETE sand Model, Upland Sandy loam Model, Rubicon Sandy loam Model, North Gower Clayey loam Model, Grenville loam Model, Snow (US) model and Snow (Sweden) model. User defined soft soil model for input by the user is also available. The model adopted in this research has parameter settings as shown in table 1:

Simulation

Simulation was done for both linear motion and also Steering motion. After the selection of the surface terrain as explained above, for driving initial, speed of 0m/s and simulation time of 20s was used. The sprocket speed was set with function, for both the left and right track system, the function is velocity =STEP (TIME, 0.01, 0, 5,-78D). Note that the velocity should be roughly equal to the value to be obtained by multiplying initial rotating speed and the sprocket radius pitch circle else the simulation would fail.

For steering, using a steering ratio of 1.5 and simulation time of also 20s. The sprocket speed was set with function, for both the left and right track system, the velocities are =STEP (TIME, 0.01, 0, 5,-78D) and STEP (TIME, 0.01, 0, 5,-52D) respectively.

Results And Discussions

After the simulation alot of parts (components) of the miner can be studied, but here the bushing forces acting on the track are studied in order to know the nature of the track loading. Figures 4 to 9 show the bushing forces acting on the track. It can be observed that during driving both the right and left tracks have the same pattern of force distribution but with the right track having a higher value than the left track. The difference between the track forces is more during driving in the normal plane than during inclination this is due to the umbilical loading.

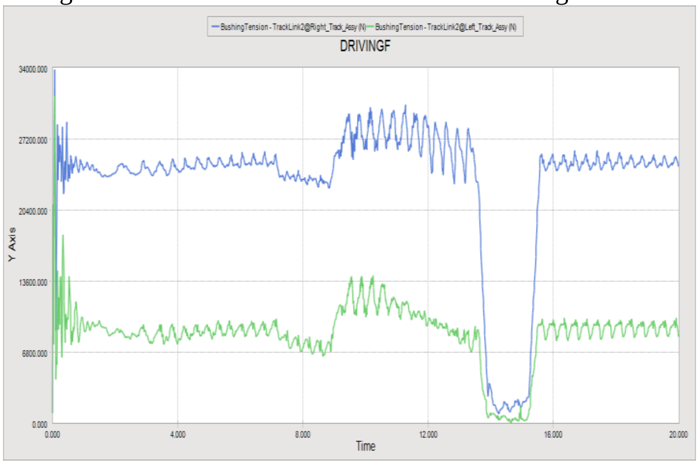

Figure 4. Bushing Tension Forces during Driving Normal Plane

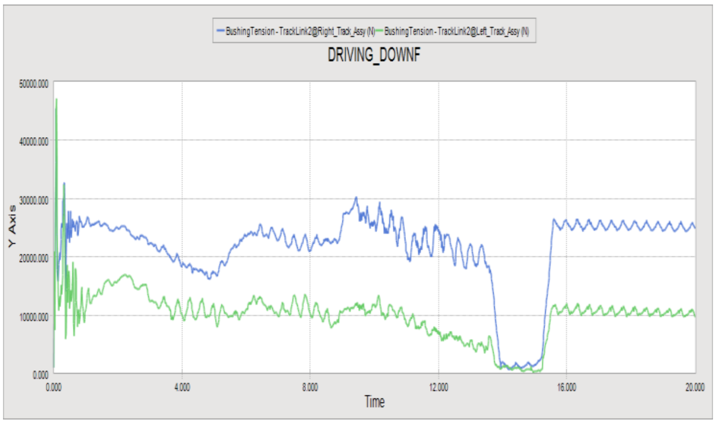

Figure 5. Bushing Tension Forces during Driving Downwards

Table 1: Soil Parameters Used

Symbol	Meaning	Value
kc	Terrain Stiffness	4.7613 e-004
kφ	Terrain Stiffness	7.6603 e-004
N	Exponential number	1.1
C	Cohesion	1.04 e-003
	Shearing angle	28
K	Shearing deformation modulus	25
	Sinkage ratio	5 e-002

Table 2 Parameters of Miner

Symbol	Meaning	Value		Symbol	Meaning	Value
Wt	Track width	0.4644m		WoL	Track-link outer width	136mm
Lt	Track length	2.1600m		LL	Track-link length	239 mm
St	Steering ratio	1.3380		HL	Track-link height	86mm
Fu	Umbilical Force	1500N		Riw	Idler radius	330mm
Hg	Height of the COG	0.9m		Rif	Idler flange radius	352mm
e	Eccentricity of miner.	0.016 Lt		Wit	Idler total width	150mm
W	Weight of miner	11000N		Wif	Idler flange width	42mm
Wst	Width of sprocket	46mm		Wrwh	Road-wheel hub width	42mm
T	Number of sprocket teeth	26		Rrwh	Road wheel hub radius	40mm
Rp	Pitch circle radius	367		Wrww	RW and hub width	140mm
Rw	Sprocket wheel radius	165		Rrww	RW radius	70mm
Ww	Width between wheels	112		Wrwt	RW total width	184mm
Wgt	Width of grouser	464mm		Rrwf	RW flange radius	80mm
Tg	Grouser thickness	10mm		Nrw	Number of RW	6
Lg	Grouser base length	10mm		Wcf	Carrier flange width	42mm
Hg	Grouser height	70mm		Rcw	Carrier radius	45mm
Gp	Grouser pitch	211		Wct	Carrier total width	150mm
Ng	Number of grousers	135		Rcf	Carrier flange radius	60mm
rpL	Track shoe pin radius	24mm		Wbf	Track frame depth	21mm
Lp	Track shoe pin length	174mm		Lbf	Track frame length	1783mm
WiL	Track-link inner width	52mm		Hbf	Track frame height	367mm

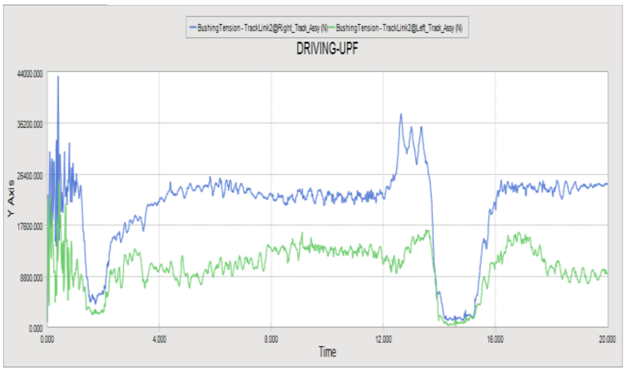

Figure 6 Bushing Tension Forces during Driving Upwards

At steering condition (i.e. during turning) the right track which is the outer track and the left track which is the inner track are not having the same force distribution pattern. They are interwoven and decaying, with the decay occurring earlier in the outer track.

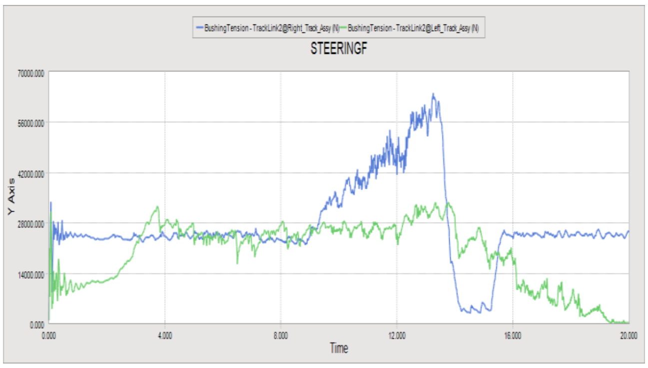

Figure 7 Bushing Tension Forces during Steering Plain

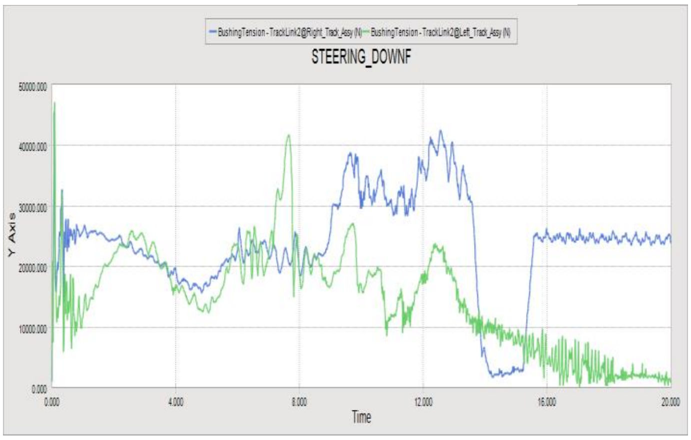

Figure 8 Bushing Tension Forces during Steering Downwards

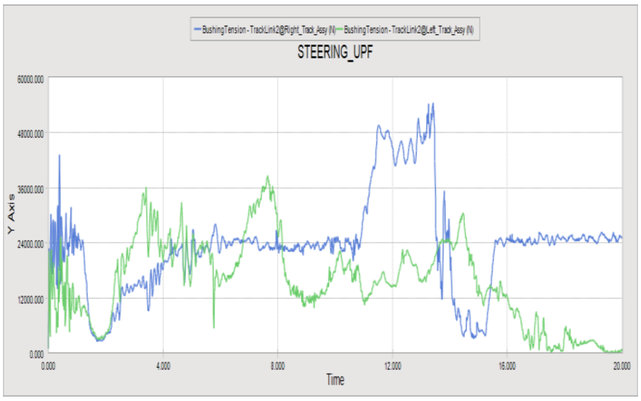

Figure 9 Bushing Tension Forces during Steering Upwards

Conclusion

In this paper we simulated a miner track system using RecurDyn. It shows that the system can be optimized and can work efficiently. The motion of the system can also be viewed through the animation of RecurDyn. This shows that the Multibody simulation package of RecurDyn is an efficient and suitable one for virtual analysis of constructing a complicated system like a miner.

This type of simulation can provides a platform for designing and virtual real-time control of miner movement during operation in the near future. This concept of development would be able to reduce cost of equipment in deep sea mining.

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