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It is believed that the behavior of oil sands can be understood better if it is modeled and simulated by using a dynamic model with which dynamic loads can be applied on the oil sand terrain when the system moves. To achieve this objective, the GAP dynamics, track-oil sand contact and load-deformation oil sand models are developed using the Newton-Euler formulations. e main objectives of this paper are developing the: (i) dynamic torque model for the GAP carriages; (ii) track-oil sands contact force model; (iii) load deformation model; and (iv) virtual prototype model and simulation of the GAP-oil sands formation interactions.

e rst two models are multi degrees-of–freedom (DOF) and non-linear multi-body dynamic systems [10] and they yield the system

Citation:

$$K_2 = mr_1^2 \; \cos T_1 + \cos 2 T_1 \left(\tfrac{1}{4} \sin_1 + T \; \cos_1 \; T \tan \right) \; / \quad (8)$$

$$\tan \; H = \tan \; T_1 \quad (9)$$

Substituting equation 9 into equations 7 and 8 yields equations 10 and 11.

$$K_1 = I + \; 2m_1^2 \; \sin^2 \; T_1 \left(1 + \; 2\cos T_1 \right) \quad (10)$$

$$K_2 = \; 2m_1^2 \; \sin_1 \left(T\cos_1 T + \cos 2 \; T_1 \right) \quad (11)$$

e driving torque of the GAP system can be obtained using equations 1, 2, 3, 10 and 11. As illustrated by these equations, the dynamic torque is proportional to the mass, angular displacements and velocities and friction between carriage and the oil sands terrain. us, the torque requirements of the GAP system must be examined in detail using varying parameters of these dependent variables.

Track-oil sands contact: Figure 4 illustrates the three components of the contact force generated as the GAP track system interacts with the oil sand terrain. ey are the normal reaction, F_n, lateral resistance, F_t, and longitudinal reaction, F_l, forces. e contact force between track and oil sand has a component that acts in the direction of contact normal at the track-oil sands contact patch. is component is used to calculate the normal reaction. e contact force is dependent on oil sand de ection and its rate of change, both measured along the track normal vector. e de ection and rate of change are obtained by the sti ness and damping of the oil sand model. e normal reaction function [13] is then given by equation 12.

$$f(t) = \begin{Bmatrix} F_n \\ F_t \\ F_l \end{Bmatrix} \quad (20)$$

[M] is the mass matrix; m is the mass of oil sand unit; J is the mass moment of inertia about the center of gravity; [C] is the dashpot coefficient matrix; [K] is the stiffness matrix; {X} is the displacement vector, {X}={x}, x is the linear displacement of the center of gravity, and is the angular displacement of the unit; {F} is the external force vector; f(t) is the external force applied to the unit; and M(t) is the moment applied to the unit. Equation 15 combines motion, damping and mechanical deformation of oil sands. The deformation of oil sands can be calculated by mass, elastic modulus and damping characteristic of oil sand unit (Figure 5). The sum of all oil sand units shown in figure 2 gives the oil sands load-deformation of the GAP system.

Virtual prototype modeling and simulation

with temperature. e friction coe cient between oil sands terrain and carriage is variable under di erent weather conditions; it is larger in the summer than in the winter. In order to operate the GAP system under the variable weather conditions, the driving torque has to be adjusted for changes in the friction coe cient. e higher the temperature, the

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decreasing bitumen content. erefore oil sand deformation is larger when the GAP system is operated on oil sand surface of higher bitumen content than on oil sand surface of lower bitumen content.

Conclusions

Virtual prototype simulators are developed in the ADAMS simulation environment to examine the GAP torque requirements and the GAP carriage-oil sand terrain interactions based on the Newton-Euler multi-body dynamics and soil mechanics. e interactions of the oil sand terrain with the GAP system have been studied to understand the e ects of angular velocity, friction coe cient and load on driving torque of the system. e 3D virtual prototype simulators of the GAP system and carriage-terrain are validated with real-world data. e results show that load and friction have greater in uence on maximum driving torque than angular velocity. us, in order to reduce the driving torque of the GAP system, ground condition improvements and the reduction of system weight are very important. e dynamic simulation of track-oil sand interaction shows that the oil sand terrain deformation increases during the carriage motion. e simulation of the e ect of load on oil sand deformation indicates that maximum deformation increases non-linearly with varying load from 0 to 60t. e applied load has a great in uence on deformation. e simulation of the e ect of oil sand properties on deformation shows that deformation is larger for lower elastic modulus. Temperature and bitumen content variations also have great in uence on the oil sand deformation. Future research will expand current models to include the whole GAP load-oil sand deformation model simulation. Further developments are required for changing the load-deformation model into elastic-plastic nite element model for examining the bearing capacity of oil sands.

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