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STUDY OF EFFECTS OF TERRAIN PARAMETERS ON TRACKED VEHICLE MANOEUVERABILITY

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Abstract. This article is aimed to conclude the results of the study conducted using simulation software "Universal Mechanism" seeking to determine tracked vehicle manoeuvrability under different terrain conditions and at different constant velocities. The main significant parameters of the simulation are presented. Results are presented graphically with each set of graphs corresponding to specific velocity at which the simulation was conducted. Conclusions are presented based on simulation results.

Keywords: simulation, tracked vehicles, track-terrain interaction, vehicle stability.

Introduction

In recent years virtual dynamic system simulation has become very important in the design and development stage, as new strategies can be examined without expensive measurements and with reduced time. (Smith *et al.* 2011)

Soil properties play an important role in determining the performance of off-road vehicles. (Al-Milli *et al.* 2010) When designing and operating a tracked vehicle it is of utmost concern that the vehicle is able to follow the desired trajectory at typical operating speeds. It is known that under certain conditions a tracked vehicle may lose control to a certain extent due to track slippage, sinking or other terrain related factors. Thus, when evaluating vehicle control and manoeuvrability operating conditions should always be considered as having higher impact factor on tracked vehicle dynamics.

The study described in this article was conducted using "Universal Mechanism" simulation software. While certain limitations in regards to the vehicle model parameters were present (e.g. insufficient effect simulation from tracked vehicle model modifications), the aforementioned simulation software was suited for this study sufficiently.

The study was conducted iterating vehicle constant moving velocities as the simulation was run using different types of terrain. It should be noted, that both tracked vehicle model and terrain parameter sets were provided as part of the "Universal Mechanism" environment, thus reducing the study preparations to setting the simulation conditions directly without the need for additional modelling.

1. Simulation environment and parameters

As mentioned beforehand, the tracked vehicle model was provided with the simulation software. As can be seen from Fig. 1, the model features an 8000 kg tracked vehicle which has six suspension and road wheels and three rollers per track. The vehicle model had no significant modifications and was tested for stability before the experiment was conducted.

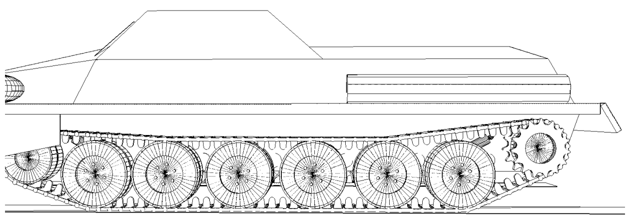

Fig. 1. Tracked vehicle model used for simulation. Provided with "Universal Mechanism" and implemented without significant modifications

The simulation involves running the tracked vehicle at predefined constant velocity through predetermined course defined by a certain trajectory. The trajectory itself resembles a double lane switching vehicle test, as seen on Fig. 2. Vehicle control is defined by a control algorithm that is made to realistically resemble driver's control. It is

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set to follow the predetermined trajectory with a 0.15 second reaction delay.

The simulation is conducted with vehicle maintaining a predefined constant velocity. It is set to iterate from 4 to 12 m/s with a 2 m/s increment.

Terrain is defined by the following parameters: exponent of deformation, cohesive modulus, friction modulus, factor of cohesion, angle of resistance, shear elasticity constant as well as two re- unloading constants. The parameter sets of terrain used during this study are presented in the following tables (Table 1 and 2).

The tracked vehicle model's element coordinates are pre-defined within stable starting conditions so that model condition is guaranteed to be stable from the start of the experiment.

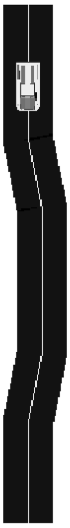

Fig. 2. Desired trajectory defined within the simulation software. Tracked vehicle can be seen on the top side of the figure (road strip is 7 m wide)

Table 1. Terrain parameter sets used during simulation

Terrain identification	Dry sand, LLL	LETE sand, Wong	Sandy loam, LLL: 15	Clayey soil, Thailand: 38
Exponent of deformation	1.1	0.79000002	0.69999	0.5
Cohesive modulus	0.94999999	102	5.27	13.19
Friction modulus	1528.4301	5301	1515.04	692.15
Factor of cohesion	1.04	1.3	1.72	4.1399
Angle of resistance (deg)	28	31.1	29	13
Shear elasticity constant *K* (mm)	11.4	11.3	11	21.2
Re- unloading constant k_0 (kPa/m)	0	0	0	0
Re- unloading constant *Au* (kPa/m^2)	86000	86000	86000	63000

Table 2. Continuation of Table 1

Terrain identification	Heavy clay, WES: 25	Lean clay, WES: 22	Snow, 1 Harrison
Exponent of deformation	0.13	0.2	1.6
Cohesive modulus	12.7	16.43	4.3699
Friction modulus	1555.95	1724.69	196.72
Factor of cohesion	68.9499	68.9499	1.03
Angle of resistance (deg)	34	20	19.7
Shear elasticity constant *K* (mm)	11.5	10	30
Re- unloading constant k_0 (kPa/m)	0	0	0
Re- unloading constant *Au* (kPa/m^2)	63 000	63 000	86 000

As can be seen from the tables presented above, the simulation was conducted on seven well-defined kinds of terrain.

2. Simulation results

The simulation results are set to be presented as deviation from the desired path (trajectory). As can be seen in some cases, this deviation may remain constant and relatively large after the first curve (Fig. 2) as the vehicle does not have enough control to return to the desired path.

The following set of figures (Fig. 3–7) shows the deviation in meters at during the simulation time period.

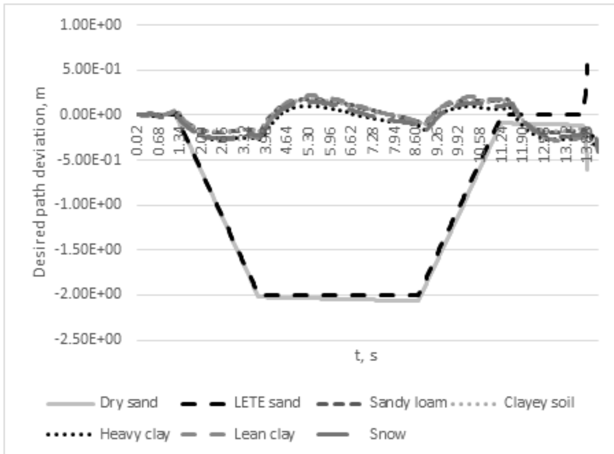

Fig. 3. Desired path deviation at 4 m/s (14.4 km/h) velocity

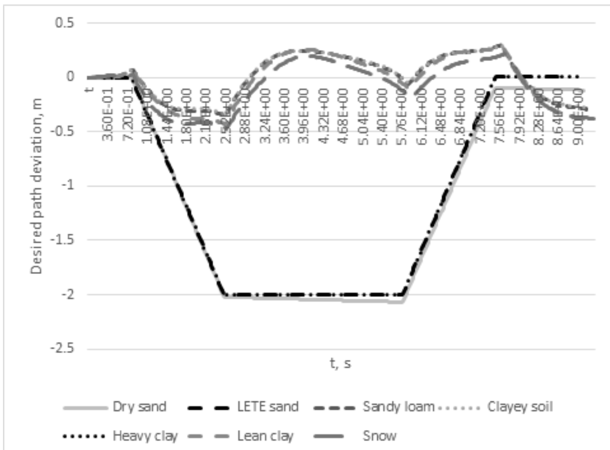

Fig. 4. Desired path deviation at 6 m/s (21.6 km/h) velocity

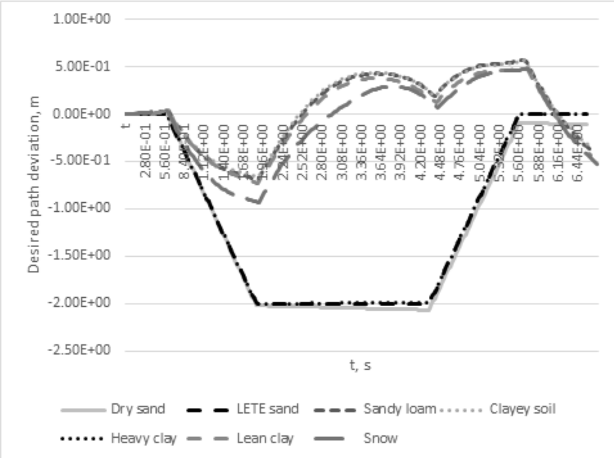

Fig. 5. Desired path deviation at 8 m/s (28.8 km/h) velocity

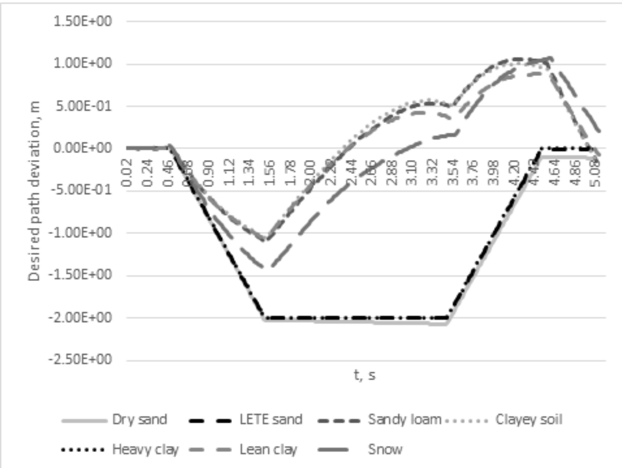

Fig. 6. Desired path deviation at 10 m/s (36 km/h) velocity

From the above figures two cases can be established: loss of control with certain types of terrain to the point where the vehicle has no capabilities to follow the desired path, which can be monitored at all simulated velocities and situations where the deviation remains relatively manageable and increases with vehicle velocity.

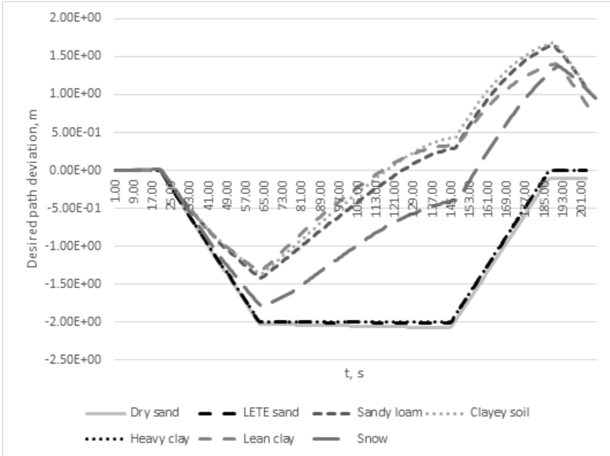

Fig. 7. Desired path deviation at 12 m/s (43.2 km/h) velocity

Conclusions

Terrain parameters have a significant influence on vehicle manoeuvrability and dynamics in general. In some cases control over vehicle trajectory can be lost even at speeds considered low on other occasions.

It was established that with dry sand, LETE sand, and heavy clay terrain parameter set during the simulation the desired path deviation exceeded the maximum value of 2 meters due to loss of vehicle control at all given velocities.

Across the remainder of terrain parameter sets general desired path deviation value changes have the same tendencies; however, the amplitude of deviations, as one would naturally assume, was determined to be higher at higher vehicle travel velocity. With lower velocities (4 and 6 m/s) the deviation never exceeded 0.5 m, with increasing velocities rapid increase in deviation can be noticed, which exceeds 1.7 m at 12 m/s.

With higher velocities loss of vehicle control becomes more apparent as the deviation becomes more significant as opposed to remaining more or less the same in case of lower velocities.

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