Annex U1 – VSDC FINAL REPORT – CHAPTER X

Note: This Annex appears in its original format.

Chapter X – SIMULATIONS OF WHEELED VEHICLE PERFORMANCE BY NWVPM (PHASE I)

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X.1 GOALS

The objective of this chapter is to highlight the ground vehicle mobility simulation and analysis using the Nepean Wheeled Vehicle Performance Model (NWVPM) and to identify the input terrain and vehicle parameters required. It constitutes part of the work performed by Vehicle Systems Development Corporation for the Phase 1 of the Next Generation NATO Reference Mobility Model Cooperative Demonstration of Technology event.

X.2 INTRODUCTION

To realistically predict the mobility of a military ground vehicle in relation to its mission, a reliable simulation model (or models) is required. In this chapter, a simulation model, known as the Nepean Wheeled Vehicle Performance Model (NWVPM), developed by Vehicle Systems Development Corporation (VSDC), Toronto, Ontario, Canada, is introduced. NWVPM is designed for predicting the cross-country performance (i.e., tractive or drawbar performance) of off-road wheeled vehicles under steady-state conditions on deformable terrain. Steady-state cross-country performance is a cornerstone for evaluating vehicle off-road mobility, and is the basis for predicting mobility metrics, such as Go/NoGo, speed-made-good, and drawbar pull coefficient (the ratio of vehicle drawbar pull to vehicle gross weight) at the nominal slip.

In this chapter, the following topics are discussed:
- (A) The approach to the development of NWVPM and its unique features.
- (B) Identification of all vehicle design parameters required for predicting the cross-country performance of the FED-Alpha vehicle by NWVPM.
- (C) Identification of the types of terrain data necessary for simulating the cross-country performance of the FED-Alpha vehicle by NWVPM.
- (D) Applications of NWVPM to predicting vehicle performance on notional terrains, in preparation for the Phase II study on comparing the performance of the FED-Alpha vehicle predicted by NWVPM with live test results.
- (E) Applications of NWVPM to predicting vehicle performance on design of experiment (DOE) points, in preparation for predicting the performance of the FED-Alpha vehicle for uncertainty quantification maps.

X.3 THE NEPEAN WHEELED VEHICLE PERFORMANCE MODEL (NWVPM)

X.3.1 Approaches and Features

NWVPM is based on the analysis of the mechanics of tire-terrain interaction and on the prediction of the normal pressure and shear stress distributions on the tire-terrain interface. The normal pressure distribution on the tire-terrain contact patch is predicted using the pressure-sinkage parameters and the parameters characterizing the response of terrain to repetitive loading, which have now become known as the Bekker-Wong terrain parameters [1, 2, 3]. It should be noted that the Bekker pressure-sinkage equation is a monotonically increasing function of sinkage. Only by taking into account the response of terrain to repetitive loading, will one be able to adequately predict the variation of normal pressure on the tire-terrain interface and the multi-pass effect on terrain behaviour [1, 2].

Dependent on the type of terrain, the shear stress on the tire-terrain interface is characterized using different models [1, 2, 4]. For mineral terrain, including fine-grained and coarse-grained soils, the Janosi-Hanamoto equation is commonly used [5]. For organic terrain (muskeg or tundra), a hump equation is employed [1, 2, 4]. For frozen snow, dry clayey soil, dense mineral terrain and the like, the shear stress initially increases rapidly with the increase of shear displacement and reaches a peak. With the further increase of shear displacement, the shear stress decreases and approaches a more or less constant residual value. For this type of shearing characteristics, the Wong equation is generally used [4].

In NWVPM, the method for predicting tire performance is dependent on the operating mode of a tire, whether rigid or flexible. The tire operating mode on deformable terrain is predicted using a parameter known as the critical pressure, which is dependent on the tire load, inflation pressure, and terrain characteristics [1, 2, 6]. For instance, on very soft soil, the deflection of a tire is relatively small in comparison with the deformation of the terrain and the tire may behave like a rigid rim, even at moderate inflation pressures. On firm terrain, even at high inflation pressures, a tire may still have substantial deflection in comparison with the deformation of the terrain, and the tire is regarded as flexible. In NWVPM, methods are developed for the analysis of rigid wheel- and flexible tire-terrain interaction and for the prediction of their respective performance [1, 2].

For predicting tire performance on deformable terrain, the ground pressure of a tire is required, which is a function of tire load and inflation pressure. Tire ground pressure at a given inflation pressure is taken as the ratio of the tire load to the nominal (gross) contact area on a firm surface [7]. The data on tire nominal contact areas on firm ground for different inflation pressures and normal loads are generally available from tire manufacturers.

For predicting the proportions of thrust developed by rubber-terrain shearing and by internal shearing of terrain, the ratio of rubber contact area to the nominal contact area of the tire is required and is determined by the ratio of specific contact area to the nominal contact area [8].

On deformable terrain, the normal load on the tire is supported by the vertical components of both the normal pressure and shear stress on the tire-terrain interface. The motion resistance acting on the tire is caused by the horizontal component of the normal pressure. The thrust is developed by the horizontal component of the shear stress on the tire-terrain interface, in part by rubber-terrain shearing and in part by internal terrain shearing. The resultant vertical reaction of the terrain for supporting the normal load on the tire, motion resistance, and thrust are obtained by integrating the appropriate component of the normal pressure and/or shear stress over the entire contact patch. The drawbar pull developed by the tire, as determined by tire-terrain interaction, is the difference between the thrust and motion resistance.

Integrating the methods for predicting tire performance on deformable terrain with vehicle dynamics, the simulation model NWVPM is capable of predicting the cross-country performance of multi-axle wheeled vehicles under steady-state conditions on deformable terrain. The basic features of NWVPM are summarized below:

(A) It can accommodate wheeled vehicles with up to eight axles and with any combination of driven- or non-driven axles.
(B) Each axle can have up to four tire pairs and the parameters of each pair of tires may be specified individually.
(C) The track or tread (i.e., the transverse distance between the centers of a pair of the left- and right-side tires on the same axle) of each axle may be specified individually. If the tracks of the front and rear axles of a two-axle vehicle are the same, then the tires on the rear axle run in the ruts formed by the tires of the front axle in straight-line motion. NWVPM takes into account the "multi-pass effects" on terrain properties in predicting the performance of the rear tires. NWVPM can also accommodate the situation where the tracks of the front and rear axles are different and the rear tires run partly in the ruts formed by the front tires and partly on undisturbed terrain.
(D) The dynamic load transfer between axles due to drawbar pull or gradient is taken into account.
(E) The effects of suspensions on load distribution among axles are taken into consideration.
(F) On exceedingly soft terrain where wheel sinkage is greater than vehicle ground clearance, the vehicle belly may come into contact with the terrain surface. The capability of NWVPM can be extended to take into account the effects of the load supported by the belly and the associated belly drag on the cross-country performance of the vehicle.
(G) Results of analytical and experimental studies indicate that for an all-wheel-drive vehicle to achieve the optimal drawbar performance, the slip of all driven wheels must be the same [9, 10, 11, 12]. NWVPM is designed for predicting the optimal cross-country performance of an all-wheel-drive vehicle, with the slips of all driven wheels being the same.

As no generally accepted methods for predicting the additional tire sinkage due to slip (or slip-sinkage) are currently available, NWVPM does not take into account the effects of slip-sinkage on vehicle performance in its current version. It should be noted, however, that the development of additional sinkage due to slip depends not only on the slip but also on the tire-terrain contact time. The time of an element of the terrain interacting with the tire is dependent on the length of the tire contact patch and vehicle speed. For instance, if the length of the tire contact patch is 0.1 m and the vehicle speed is 2 m/s (7.2 km/h or 4.5 mph), then the time of a terrain element in contact with the tire will be relatively short of 0.05 s. For such a short contact time, even if at moderate slips, the additional sinkage due to slip may not have sufficient time to develop. Under these circumstances, slip-sinkage may be insignificant and may not necessarily have substantial impact on vehicle performance on deformable terrain. The issue of slip-sinkage requires further investigation.

X.3.2 Input terrain parameters

The Bekker-Wong terrain parameters required by NWVPM are summarized in Table X-1.

Table X-1: Terrain parameters required by NWVPM for mineral terrain.

Type of parameters	Symbols of terrain parameters
Pressure-sinkage	k_c , k_φ , n
Repetitive loading	k_0 , A_u
Terrain internal shearing	c , φ , K
Rubber-terrain shearing	c_{ru} , φ_{ru} , K_{ru}
Vehicle belly-terrain shearing*	c_b , φ_b , K_b

*For predicting belly drag due to belly-terrain interaction, when tire sinkage is greater than vehicle ground clearance.

X.3.3 Input vehicle and tire parameters

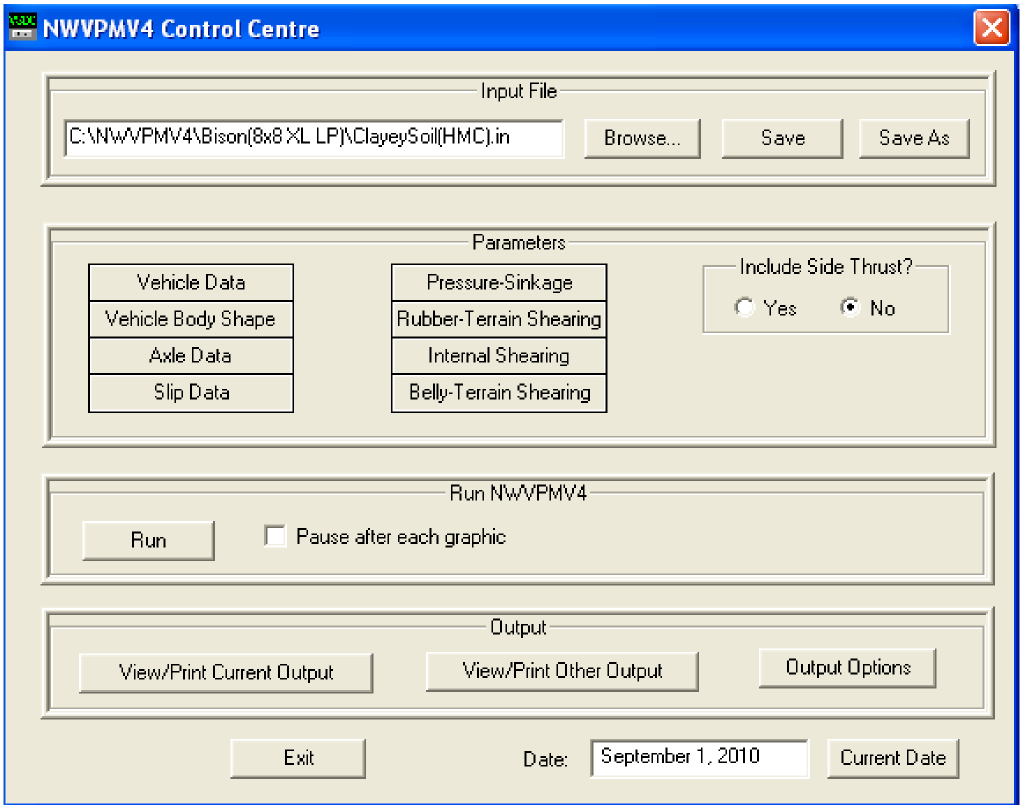
The major vehicle, axle and tire parameters required by NWVPM are summarized in Table X-2.

Table X-2: Vehicle, axle and tire parameters required for NWVPM.

Vehicle parameters	**Tire parameters**
Total weight	Diameter
Center of gravity, x-coordinate	Effective radius
Center of gravity, y-coordinate	Tread width
Drawbar hitch, x-coordinate	Section height
Drawbar hitch, y-coordinate	Lug area/Carcass area (Specific/Nominal contact area)
Axle Parameters	
Axle load	Lug height
Axle suspension stiffness	Lug width
Axle clearance	Inflation pressure
Axle x-coordinate	Ground pressure (Tire load/Nominal contact area)
Drive axle (Yes/No)	
Tire identification	Tire type (Radial or Bias)
Number of tire pairs	Internal loss coefficient
Track (tread) of axle	

X.3.4 Operation

The analytical framework for predicting the cross-country performance of wheeled vehicles on deformable terrain described above is implemented in the simulation model NWVPM in a user-friendly manner. Figure X-1 shows the control center for operating NWVPM.



Input File: C:\NWVPMV4\Bison(8x8 XL LP)\ClayeySoil(HMC).in

Include Side Thrust? ○ Yes ● No

☐ Pause after each graphic

Date: September 1, 2010

Figure X-1: Control center for the operation of NWVPM, as shown on the monitor screen.

All vehicle and terrain data are input to NWVPM using the dialog (edit) box format, for the convenience of the user. NWVPM runs on Microsoft Windows operating systems, including XP, 7, 8, and 10.

X.3.5 Output

The output of NWVPM for cross-country performance metrics is primarily in graphical or tabular format. The major output performance metrics include: sinkages of tires on various axles, vehicle motion resistance, thrust, drawbar pull, tractive efficiency, as determined by vehicle-terrain interaction. The vehicle motion resistance, thrust, and drawbar pull normalized with respect to vehicle weight and expressed in percentage are also part of the output of NWVPM.

X.3.6 Applications

NWVPM has been employed to assist governmental agencies in Canada and the United States in the evaluation of the mobility of light armored vehicles and military logistics wheeled vehicles. NWVPM has also been licensed to governmental agencies in North America and Asia.

X.4 MAJOR DESIGN PARAMETERS FOR THE FED-ALPHA VEHICLE

Based on vehicle data released to VSDC, the major design parameters of the FED-Alpha vehicle used in the predictions of drawbar performance by NWVPM are summarized in Table X-3.

Table X-3: Major vehicle parameters of the FED-Alpha vehicle.

Total vehicle weight	53.755 kN
Front axle load (static)	27.845 kN
Rear axle load (static)	25.910 kN
Front axle track width	197.60 cm
Rear axle track width	195.91 cm
Front axle suspension stiffness (average)	2.941 kN/cm
Rear axle suspension stiffness (average)	3.693 kN/cm
CG longitudinal location from the center of front axle	159.16 cm
CG height from the ground	99.14 cm
Drawbar hitch longitudinal location from the center of front axle	423.78 cm
Drawbar hitch height from the ground	108.71 cm
Ground clearance	40.64 cm

Figure X-2 shows the sketch of the side view of the FED-Alpha vehicle, which is part of the output of NWVPM.

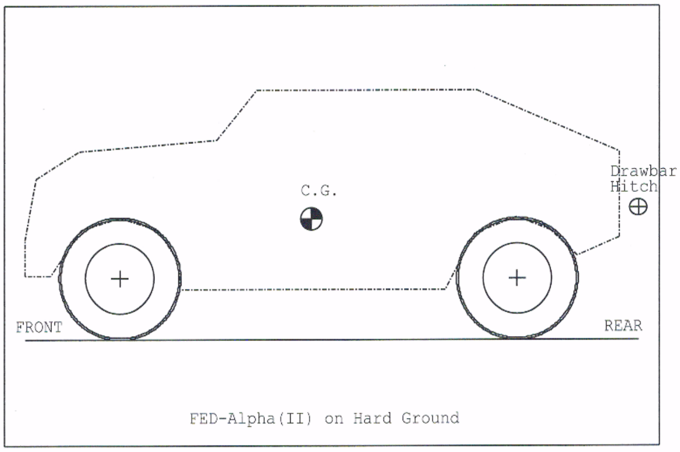


Figure X-2: A sketch of the side view of the FED-Alpha vehicle, as part of the output from NWVPM.

The major tire parameters of the FED-Alpha vehicle used in the predictions by NWVPM are summarized in Table X-4 [8].

Table X-4: Major tire parameters of the FED-Alpha vehicle.

Tire name	Goodyear 335/65R22.5
Effective tire radius	45.3 cm
Tread width	33.50 cm
Lug area/Carcass area (Specific/Nominal contact area)	0.58
Lug height	1.60 cm
Lug width	6.0 cm
Inflation pressure	241 kPa
Ground pressure (Tire load/Nominal contact area)	247 kPa

The effective tire radius is based on the data provided by Keweenaw Research Center (KRC), Michigan Technological University. The ratio of lug area to carcass area (specific contact area to nominal contact area) is based on the tire data presented in [8]. This ratio is independent of tire inflation pressure. The ground pressure is the tire load divided by the nominal contact area on firm ground. The nominal tire contact area at inflation pressure of 241 kPa (35 psi) is determined by interpolation of the nominal contact area at inflation pressure of 206 kPa (30 psi) and that at inflation pressure of 414 kPa (60 psi), from tire data given in [8].

X.5 NOTIONAL TERRAINS USED FOR TESTING THE CAPABILITY OF NWVPM

To test its capability, NWVPM was used to predict the cross-country performance of the FED-Alpha vehicle on various types of notional terrain and slopes, with data provided by the KRC. The features and characteristics of these notional terrains are summarized in Table X-5.

It should be noted that the terrain parameters provided by KRC includes only the Bekker pressure-sinkage parameters n, k_c, and k_φ, and terrain internal shear strength parameters c and φ. As noted in Section X.3.2 and Table X-1, the terrain repetitive loading parameters k_0 and A_u, terrain shear deformation parameter K, and rubber-terrain shear parameters c_{ru}, φ_{ru}, and K_{ru} are required as input to NWVPM. The values of the parameters not provided by KRC were assumed by VSDC, using values of similar terrain in its data bank. A complete set of terrain parameters of various types of notional terrain used as input to NWVPM for predicting the cross-country performance of the FED-Alpha vehicle is presented in Table X-6.

It should be pointed out that using the values of k_c for Black Muck given in Table X-5, numerical difficulty was encountered in predicting the cross-country performance of the FED-Alpha vehicle by NWVPM. As a result, this value was modified for predicting vehicle performance by NWVPM, as shown in Table X-6. The value of $k_c = 5$ lb/in^{n+1} (1.8 kN/m^{n+1}) in Table X-5 for Black Muck was changed to $k_c = 12.7$ lb/in^{n+1} (4.65 kN/m^{n+1}) in Table 6.

Table X-5: Notional terrain types and slopes on various locations provided by Keweenaw Research Center for CDT Phase I study.

Terrain Type	Location	n	k_c lb/in^{n+1}	k_φ lb/in^{n+2}	c psi	φ degree	Moisture content %
Black muck	Deford-Tawas complex, 0-1% slope	0.2	5	10	2.0	11	40
	Lupton and Cathro soils, 0-1% slope	0.2	5	10	2.0	11	40
Fine sandy loam	Montreal-Net complex, 0-8% slope	0.7	4	10	0.5	30	12
	Net-Witbeck complex, 0-3% slope	0.7	4	10	0.5	30	12
	Skanee fine sandy loam, 0-3% slope	0.7	4	10	0.5	30	1 2
Loamy fine sand	Abbaye-Munising loamy fine sand, 1-8% slope	0.4	15	27	1.0	35	15
	Alcona loamy fine sand, 1-8% slope	0.4	15	27	1.0	35	15
	Munising loamy fine sand, 1-8% slope	0.4	15	27	1.0	35	15
	Munising-Abbaye-Kalkaska complex, 1-12% slope	0.4	15	27	1.0	35	15
	Munising-Abbaye-Kalkaska complex, 15-70% slope	0.4	15	27	1.0	35	15
Mucky sandy loam	Skanee-Gay complex, 0-3% slope	0.5	12	16	0.6	13	30
Sand	Assinins sand, 0-3% slope	0.8	32	42	0.2	31	7
	Au Gres sand, 0-3% slope	0.8	32	42	0.2	31	7
	Kalkaska-Waiska sand, 0-8% slope	0.8	32	42	0.2	31	7
	Kalkaska-Waiska sand, 8-15% slope	0.8	32	42	0.2	31	7
	Kalkaska-Waiska sand, 15-35% slope	0.8	32	42	0.2	31	7

Table X-6: Parameters of notional terrains used by Vehicle Systems Development Corporation for CDT Phase I study.

Terrain type	n	k_c kN/m^{n+1}	k_φ kN/m^{n+2}	c kPa	φ degree	K* cm	c_{ru}* kPa	φ_{ru}* degree	K_{ru}* cm	k_0* kN/m^3	A_u* kN/m^4	Moisture Content %
Black muck	0.2	4.65	143.7	13.79	11	2.54	6.16	8.2	2.12	0	78,820	40
Fine sandy loam	0.7	9.2	901.8	3.45	30	1.6	1.63	26.6	1.14	0	503,000	20
Loamy fine sand	0.4	11.4	809	6.9	35	1.6	3.25	31	1.14	0	503,000	15
Mucky sandy loam	0.5	13.2	692.2	4.14	13	2.54	1.85	9.7	2.12	0	78,820	30
Sand	0.8	105.8	5468.6	1.38	31	1.6	0.65	27.5	1.14	0	503,000	7

* The values of these parameters are not provided by Keweenaw Research Center and are assumed by VSDC.

X.6 CROSS-COUNTRY PERFORMANCE OF THE FED-ALPHA VEHICLE ON VARIOUS TYPES OF NOTIONAL TERRAIN PREDICTED BY NWVPM

The cross-country performances of the FED-Alpha vehicle on various types of notional terrain and slopes were predicted by NWVPM. A summary of the simulation results is presented in Table X-7. It should be noted that in the simulations, the front and rear axles are all driven and that the tires on the front and rear axles are set to the same slip. It has been demonstrated that with identical slips for all driven tires, vehicle cross-country performance will be at its optimum [9, 10, 11, 12].

Table X-7: Cross-country performance of the FED-Alpha vehicle on various types of notional terrain and slopes predicted by NWVPM.

Terrain type	**Location**	**Slope %**	**Drawbar pull coefficient at 20% slip, %**
Black muck	**Generic**	**0**	**-17.52 (NoGo)**
	Deford-Tawas complex	0	**-17.52 (NoGo)**
	Deford-Tawas complex	1	**-18.52 (NoGo)**
	Lupton and Cathro soils	0	**-17.52 (NoGo)**
	Lupton and Cathro soils	1	**-18.52 (NoGo)**
Fine sandy loam	**Generic**	**0**	**26.35**
	Montreal-Net complex	0	26.35
	Montreal-Net complex	8	18.35
	Net-Witbeck complex	0	26.35
	Net-Witbeck complex	3	23.35
	Skanee fine sandy loam	0	26.35
	Skanee fine sandy loam	3	23.35
Loamy fine sand	**Generic**	**0**	**40.88**
	Abbaye-Munising loamy fine sand	1	39.88
	Abbaye-Munising loamy fine sand	8	32.88
	Alcona loamy fine sand	1	39.88
	Alcona loamy fine sand	8	32.88
	Munising loamy fine sand	1	39.88
	Munising loamy fine sand	8	32.88
	Munising-Abbaye-Kalkaska complex	1	39.88
	Munising-Abbaye-Kalkaska complex	12	28.88
	Munising-Abbaye-Kalkaska complex	15	25.88
	Munising-Abbaye-Kalkaska complex	70	**-29.21 (NoGo)**
Mucky sandy loam	**Generic**	**0**	**-1.85 (NoGo)**
	Skanee-Gay complex	0	**-1.85 (NoGo)**
	Skanee-Gay complex	3	**-4.85 (NoGo)**
Sand	**Generic**	**0**	**35.15**
	Assinins sand	0	35.15
	Assinins sand	3	32.15
	Au Gres sand	0	35.15
	Au Gres sand	3	32.15
	Kalkaska-Waiska sand	0	35.15
	Kalkaska-Waiska sand	8	27.15
	Kalkaska-Waiska sand	15	20.15
	Kalkaska-Waiska sand	35	0.15

In common practice the drawbar pull coefficient (the ratio of drawbar pull D to vehicle weight W) at 20% slip is widely used as an indicator for cross-country mobility of an off-road vehicle. Table X-7 shows the drawbar pull coefficient at 20% slip of the FED-Alpha vehicle on various types of notional terrain and slopes predicted by NWVPM.

It should be pointed out that the drawbar pull coefficient of a vehicle not only represents its capability to push or pull equipment, implements, trailers, etc., but also its ability to accelerate or to climb slopes. For instance, if the drawbar pull coefficient at 20% slip is 30% (or 0.3) on level (horizontal) terrain, then it indicates that the vehicle has the ability to accelerate on level terrain at a rate of approximately 0.3 g. In estimating the drawbar pull coefficient at 20% slip available on an up-slope, the gravitational resisting force on an up-slope normalized with respect to vehicle normal load on the slope is equal to the slope in percentage. In this report the available drawbar pull coefficient at 20% slip on a slope $(D/W)_{slope}$ is estimated by [13]

$(D/W)_{slope} = (D/W)_{level}$ - Slope (%)
where $(D/W)_{level}$ is the drawbar pull coefficient at 20% slip on level terrain.

It should be noted if the value of $(D/W)_{slope}$ is negative, then it will indicate that the vehicle is in a NoGo situation or the vehicle is not capable of operating under steady-state conditions on the given slope.

X.7 SIMULATIONS OF THE PERFORMANCE OF THE FED-ALPHA VEHICLE AT DESIGN OF EXPERIMENT (DOE) POINTS BY NWVPM FOR UNCERTAINTY QUANTIFICATION MAPS

The cross-country performance of the FED-Alpha vehicle, as represented by its drawbar pull coefficient at 20% slip, at 100 DOE points were predicted by NWVPM for uncertainty quantification maps. The Bekker pressure-sinkage parameters n, k_c, and k_φ, and terrain internal shear strength parameters c and φ, together with slopes, for the 100 DOE points were provided by RAMDO Solutions. The terrain repetitive loading parameters k_0 and A_u, terrain shear deformation parameter K, and rubber-terrain shear parameters c_{ru}, φ_{ru}, and K_{ru}, required as input to NWVPM, were assumed by VSDC, based on the values of similar terrain in its data bank.

As noted previously, the drawbar pull coefficient at 20% slip on a slope $(D/W)_{slope}$ may be estimated by

$(D/W)_{slope} = (D/W)_{level}$ - Slope (%)
where $(D/W)_{level}$ is the drawbar pull coefficient at 20% slip on level terrain.

As pointed out previously, if the value of $(D/W)_{slope}$ is negative, then it will indicate that the vehicle is in a NoGo situation or the vehicle is not capable of operating under steady-state conditions on the given slope.

For further information on the results of the simulation of vehicle performance by NWVPM at DOE points for uncertainty quantification maps, please refer to Reference [14].

It should be noted that the provision of simulation results obtained using VSDC's software NWVPM for uncertainty quantification maps (UQM) does not necessarily constitute or imply its endorsement, recommendation, or favoring by VSDC of the methodology used for producing the UQM, and does not necessarily constitute or imply any warranty, expressed or implied, by VSDC on the validity or accuracy of the UMQ data based on the simulation results provided by VSDC.

X.8 CLOSING REMARKS

(A) This report demonstrates the applications of the Nepean Wheeled Vehicle Performance Model (NWVPM), developed by Vehicle Systems Development Corporation (VSDC), to predicting the cross-country performance of the FED-Alpha vehicle on various types of notional terrain and slopes, provided by the Keweenaw Research Center, Michigan Technological University, Houghton, MI.

(B) The results shown in Table X-7 that the FED-Alpha vehicle will be NoGo on level Black Muck terrain, as its drawbar pull coefficient is negative. It is also shown in that the FED-Alpha vehicle will be NoGo on level Mucky Sandy Loam terrain.

(C) As shown in Table X-7, on Black Muck, at the Deford-Tawas complex with slopes of 0-1% and at the Lupton and Cathro soils with slopes of 0-1%, the values of the vehicle drawbar pull coefficient at 20% slip are negative, which is an indication of NoGo for the vehicle. On Mucky Sandy Loam, at the Skanee-Gay complex with slopes of 0-3%, the values of drawbar pull coefficient at 20% slip are negative, which indicates a NoGo for the vehicle. On Loamy Fine Sand, at the Munising-Abbaye-Kalkaska complex with a slope of 70%, the value of drawbar pull coefficient at 20% slip is negative, which indicates a NoGo condition for the FED-Alpha vehicle.

(D) Simulations of the cross-country performance of the FED-Alpha vehicle, as represented by the drawbar pull coefficient at 20% slip, at the 100 Design of Experiment (DOE) points were conducted by NWVPM. The values of the Bekker pressure-sinkage parameters and shear strength parameters for the 100 DOE points were provided by RAMDO Solutions, whereas values the repetitive loading parameters, the shear deformation parameter, and the rubber-terrain shear parameters required by NWVPM, were assumed by VSDC, based on the values of similar terrain in its data bank. For details please refer to Reference [14].

Acknowledgements

The work described in this chapter was performed by Vehicle Systems Development Corporation, Toronto, Ontario, Canada, under Subcontract No. SEP1147916, administered by Alion Science and Technology Corporation, U.S.A., for the U.S. Army Tank Automotive Research, Development and Engineering Center, Warren, MI, U.S.A.

Disclaimer

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