Annex T – VSDC FINAL CDT PRESENTATION

Note: This Annex appears in its original format.

Comparison of the measured performance of the FED vehicle with that predicted using NWVPM

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Introduction

- Vehicle Systems Development Corporation (VSDC) specializes in research, development, and consulting in the area of vehicle mobility.
- It has developed two simulation models for performance and design evaluation of off-road vehicles, from cross-country performance perspective.
- One is known as NTVPM for tracked vehicles and the other is known as NWVPM for wheeled vehicles.

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NTVPM

- For single-unit or two-unit articulated tracked vehicles, with relatively short track pitch (commonly used in military vehicles), or with rubber tracks (with potential for use on a future generation of military vehicles).
- Its basic features have been substantiated with field test data on mineral terrain, muskeg, and snow-covered terrain.
- It has been employed to assist military vehicle manufacturers in the development of new products and governmental agencies in the evaluation of vehicle candidates in the procurement process, in Europe, North America, and Asia.

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NWVPM

- NWVPM is designed for predicting wheeled vehicle cross-country performance under steady-state conditions on deformable terrain. It has been employed to assist governmental agencies in North America in evaluating military wheeled vehicle performances.
- The prediction procedures are based on solving a set of non-linear dynamic equilibrium equations. For predicting steady-state performance, this approach is inherently much more efficient and effective than the time integration of a large set of equations of motion, which is employed in multi-body dynamics models.

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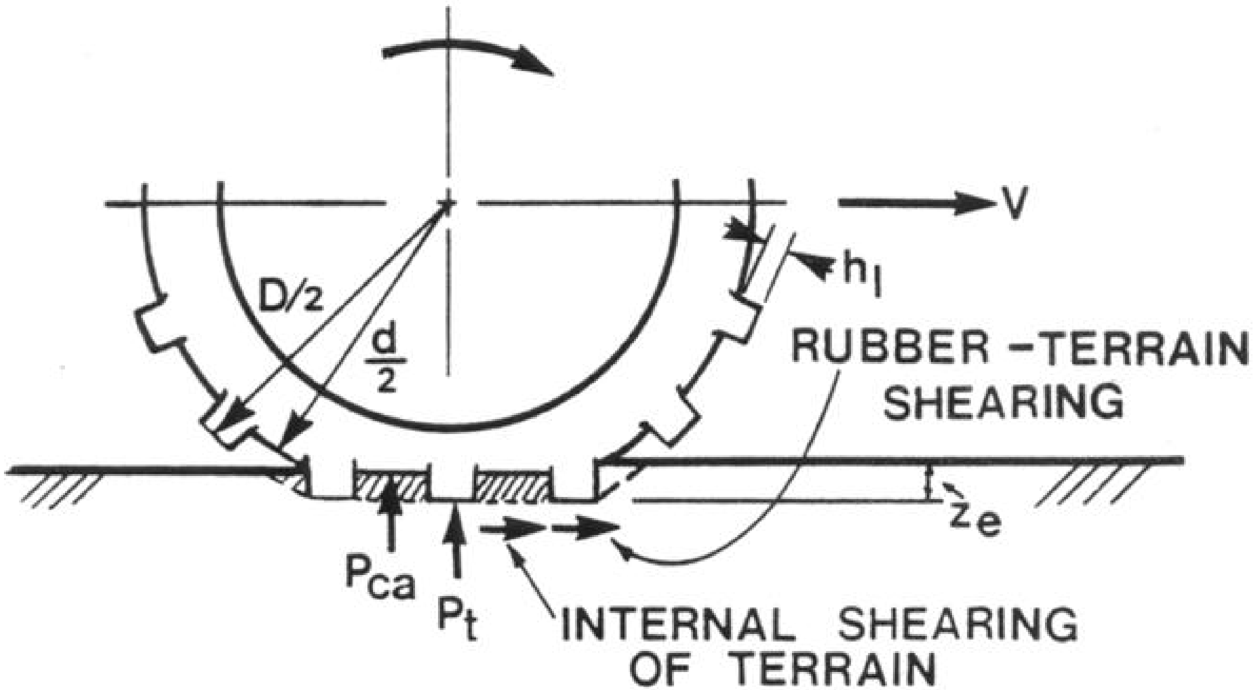
NWVPM

General Tire Model



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NWVPM

It focuses on the prediction of tire sinkage and the normal and shear stress distributions on the tire-terrain interface.

- The normal load on the tire is supported by the vertical components of both the normal and shear stresses.

- The motion resistance is derived from the horizontal components of the normal pressures.

- The thrust (tractive effort) is derived from the horizontal components of the shear stresses on the rubber grouser-terrain interface and that on the shear surface between rubber grousers.

- The drawbar pull is taken as the difference between the thrust and motion resistance.

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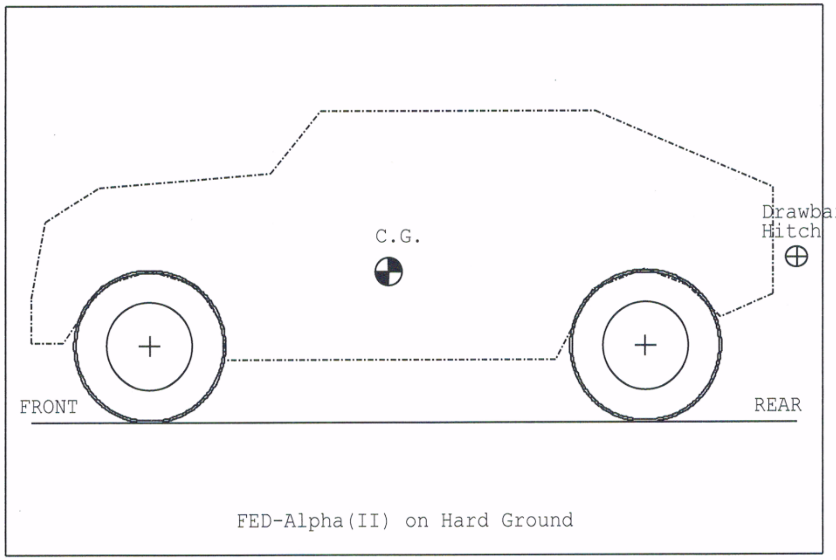
NWVPM
Vehicle Model



- **The track (distance between left and right tire centers) of each axle may be specified individually. It takes into account multi-pass effects, if the tracks of the axles are the same.**
- **Dynamic load transfer due to drawbar pull or gradient effects, etc. are taken into account.**
- **The optimal performance of AWD is predicted (i.e., equal slip for all tires).**

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Applications of NWVPM to predicting the FED performance on soil pits at KRC

1. Principal vehicle design parameters of the FED:

- Vehicle weight: 53.755 kN
- Front axle load: 27.845 kN; Rear axle load: 25.910 kN
- Wheelbase: 3,302 mm
- Wheel track: 1,976 mm
- CG position: Height - 991 mm;
  Longitudinal - 1,592 mm (from the front axle)
- All wheel drive

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Applications of NWVPM to predicting the FED vehicle performance on soil pits at KRC

2. Principal tire parameters of the FED:

- Tire type: Goodyear 335/65R22.5
- Effective rolling radius: 453 mm
- Tread width: 335 mm
- Grouser height: 16 mm
- Specific area/Nominal contact area: 0.58
- Inflation pressure: 241 kPa (35 psi)
- Nominal ground pressure (Load/Nominal contact area): 247 kPa

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NWVPM

Input Terrain Parameters

Terrain parameters measured by the bevameter are used as input to NWVPM:

- pressure-sinkage parameters
- internal terrain shear parameters
- rubber-terrain shear parameters (for vehicles with rubber tires or with rubber tracks)
- repetitive loading parameters (for evaluating multi-pass effects)
- vehicle belly-terrain shear parameters (for predicting belly drag, if sinkage greater than ground clearance)

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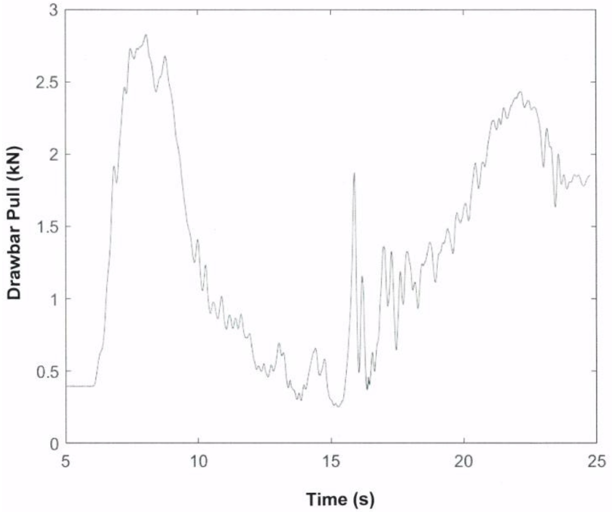
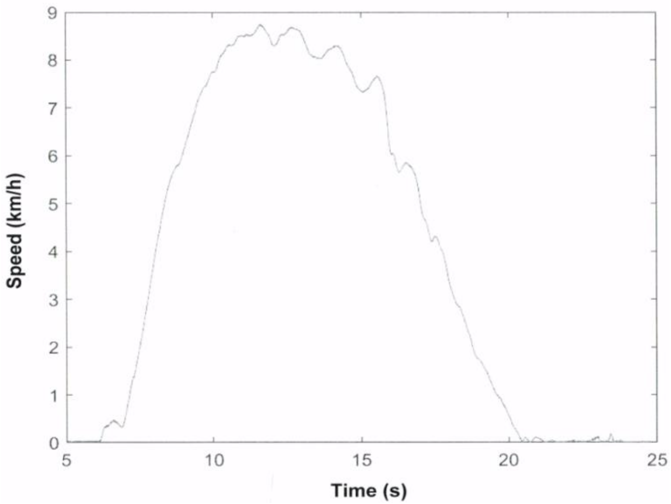
Comparison of the performance predicted by NWVPM and that measured on June 5, 2018

In common practice, drawbar performance tests are conducted under steady-state conditions. However, the performance measured on June 5, 2018 was under dynamic conditions, as shown in the graphs below. While the test data were later corrected for the inertial effect of vehicle mass, it is uncertain that this correction alone could account for all other dynamic effects on vehicle-terrain interaction.





CDT Events

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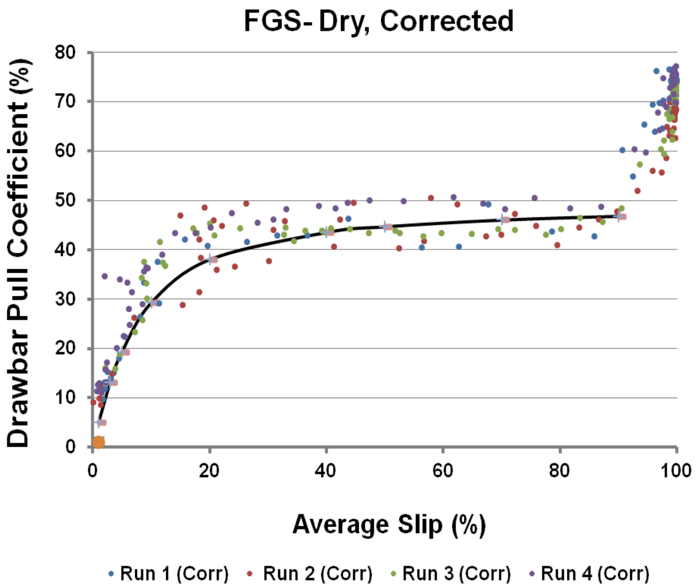

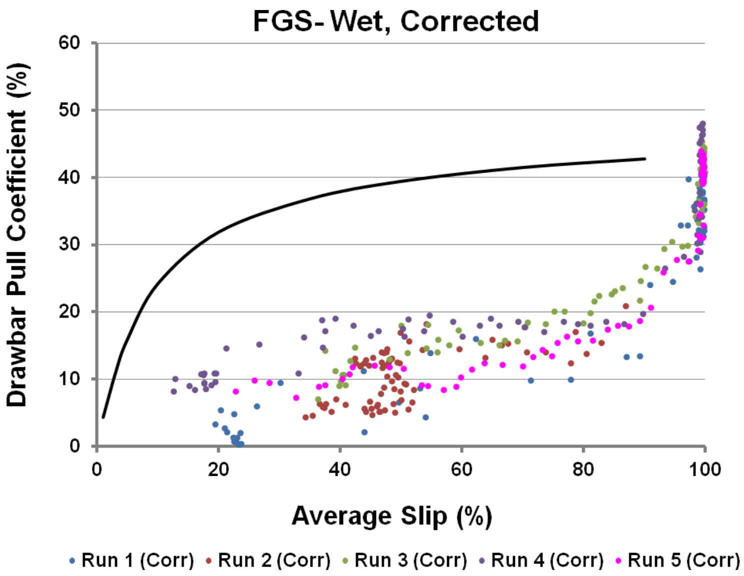

Note: **The solid line represents the performance predicted by NWVPM. The dots represent the measured data points.**

On FGS-Dry, the correlation between the predicted and measured performance is very encouraging. On FGS-Wet, there are anomalies in some of the measured data. Significant differences are found between the measured drawbar pull and the thrust derived from the measured torques on the tires. This implies abnormally high motion resistance, which is not necessarily consistent with measured rut depths. More in-depth study is needed.

CDT Events

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Comparison of the average rut depth measured on June 5, 2018 by KRC With the rut depth and motion resistance coefficient predicted by NWVPM

Date	Soil	Test	Average rut depth range measured by KRC, cm	Predicted rut depth and motion resistant coefficient range by NWVPM	
				Rut Depth Range, cm	Motion Resistance Coefficient Range, %
June 5, 2018	Coarse Grain Pit Dry	Drawbar	9 to 10	5.4 to 6*	9.5 to11.3
June 5, 2018	Fine Grain Pit Wet	Drawbar	14 to 15	14.8 to 15.9**	10 to 13.7
June 5, 2018	Fine Grain Pit Dry	Drawbar	3 to 4	3.8***	5

*Based on the mean values of terrain parameters from Test Sets 12 to 14, June 5, 2108.
** Based on the mean values of terrain parameters from Test Sets 17 and 18, June 5, 2018.
*** Based on the values of terrain parameters from Test Set 10, June 5, 2018.

CDT Events

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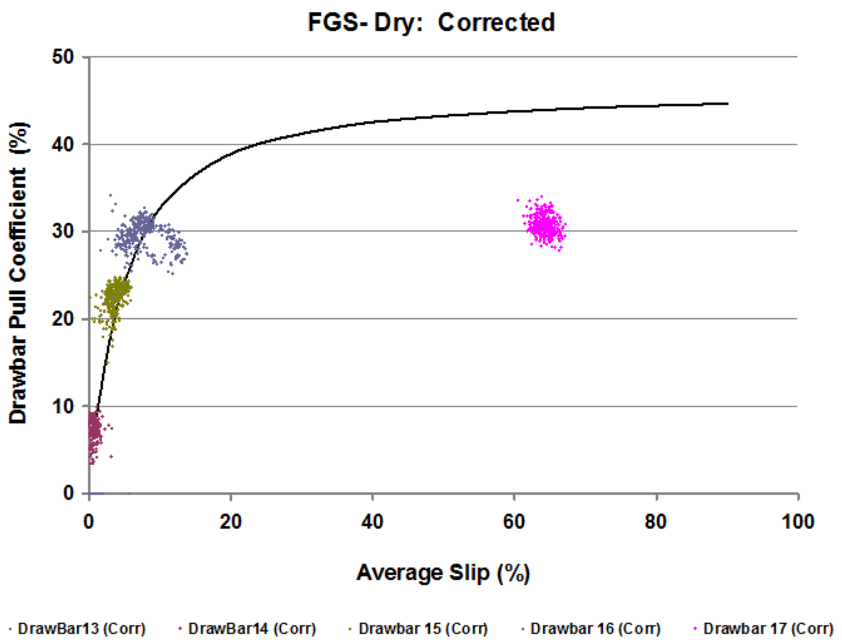
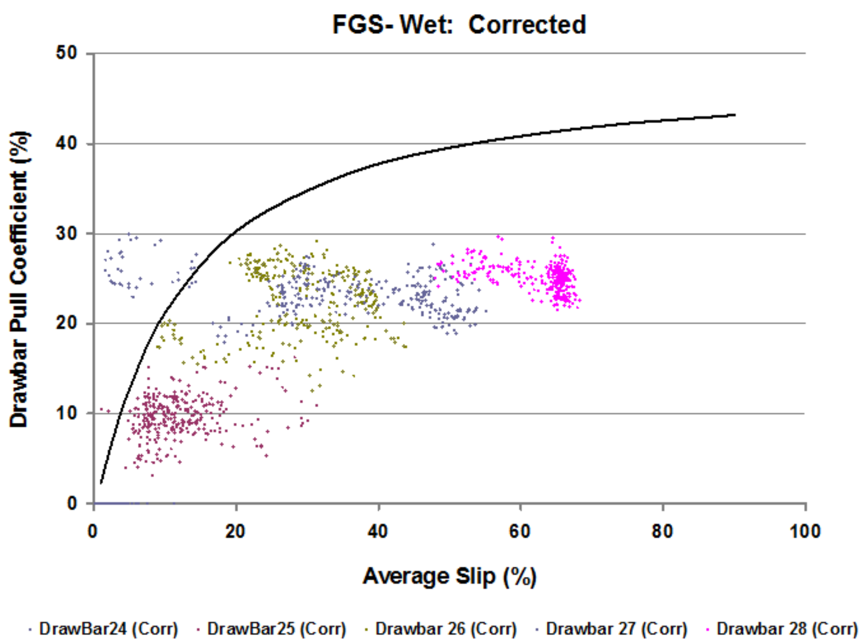
Comparison of the performance predicted by NWVPM and that measured on June 29, 2018

Vehicle performance tests under steady-state conditions were conducted by KRC on June 29, 2018.





Note: The solid line represents the performance predicted by NWVPM. The dots represent the measured data points. More in-depth study of the discrepancy is needed.

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What would be considered as a reasonable correlation between measured and predicted data in Terramechanics?

In his comments on a method for predicting pressure distributions in the soil under tire loads, the late Professor Sohne, former President of ISTVS, seemed to indicate that the discrepancy between predicted and measured values in the range of about 25% may be considered as reasonable in Terramechanics.

Following this criterion, the correlation between the measured and predicted performance by NWVPM on FGS-Dry and FGS-Wet may be evaluated accordingly.

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Closing Remarks

- The CDT events provide an opportunity to demonstrate available simulation tools for military vehicle mobility and to evaluate their potentials for the development of the Next Generation NATO Reference Mobility Model (NG-NRMM).

- Comparisons of predictions by simulation models with test results may offer guidance to software developers and the testing community for further improvements in their products and in field testing methods, respectively.

CDT Events

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Any questions?

Thank you for your attention!