Effect of Soil Moisture on Ground Hardness for Snowmobile Pass-By Noise Testing

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SNOWMOBILE PASS-BY noise testing is the current method used to determine how well different snowmobiles meet government regulations. One form of pass-by testing is defined by operating a machine to travel past a stationary microphone located at a specified position from the vehicle path. An example of a pass-by noise course is provided in Figure 1 (SAEJ192).

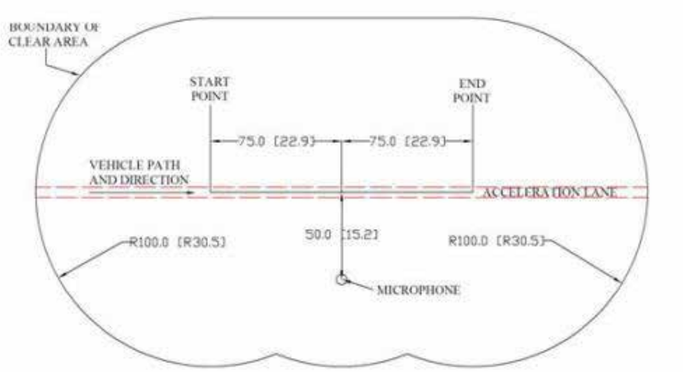

Figure 1: Pass-by Noise Course Layout

Current standards exist for noise testing of snowmobiles to be conducted on both snow and grass surfaces. The standards also allow the snowmobiles to be tested on any grass surface which is relatively flat with a grass height of no more than 3 inches. An example of a typical pass-by run with a machine is provided in Figure 2.

Figure 2: Pass-by Noise Test Run

Little is known of the effects of the different contributors to the ground conditions for this testing. Current research involves testing across varying ground and environmental conditions to determine the different contributing factors. A speaker sound source is used to determine how sound propagation is affected due to the various environmental factors while eight different snowmobiles are tested to determine how machine operation is affected by the conditions. Many different parameters are measured during the tests including: air temperature, barometric pressure, relative humidity, grass height, wind speed, wind direction, ground hardness and soil moisture. The EC-5 coupled with the ECH2O Check were selected for the soil moisture readings. Ground hardness was measured with a device of unique design to the project, the device measures the amount of force required to push a probe in a set distance. Both measurement tools are shown during field use in Figure 3.

Figure 3: Ground Hardness Tester (Left) and EC-5 with ECH2O Check (Right)

A distinct trend between soil moisture and ground hardness exists as shown in Figure 4. Different test locations were used throughout the summer months as history has shown that sound test results vary greatly from location to location. Although there does not appear to be any significant differences in the relationship between soil moisture and ground hardness from site to site, a useful conclusion can still be made with these results.

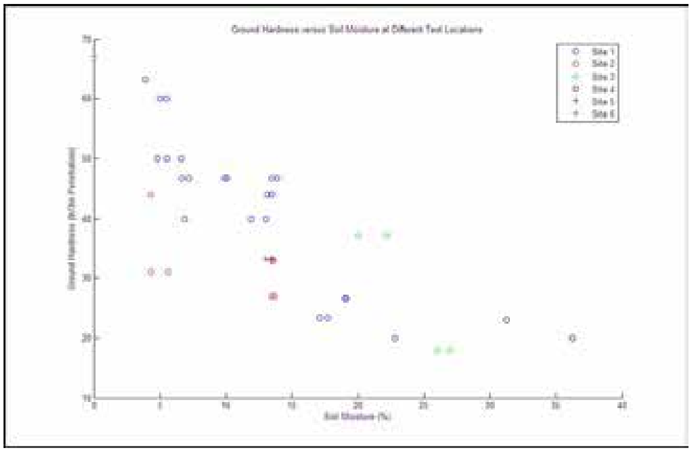

Figure 4: Ground Hardness versus Soil Moisture at Different Test Locations

Test sites 1, 4, and 5 were in a similar region within upper Wisconsin and upper Michigan. Test site 2 and 3 were in Northwest Minnesota. Test site 6 was a grass area near a parking lot where most of the sound field was over an asphalt surface.

Speaker testing was conducted using a known sound power omnidirectional sound source. The speaker remained stationary for the duration of the test and microphone recordings were made at specific locations from the speaker. Using a known sound power source allows for the prediction of sound pressure levels at given distances based on the equation below (Lord, 1980). This equation relies on the assumption of a hemispherical sound field with a perfectly reflective bottom surface.

$$p_{rms}^2 = \frac{W \rho_0 c}{2\pi R^2}$$

$$where:$$

$$p = pressure$$

$$W = sound\,power\,of\,source$$

$$\rho_0 = air\,density$$

$$c = speed\,of\,sound$$

$$R = radius\,from\,source$$

Of course, grass and soil are not perfectly reflective surfaces, therefore the differences between the predicted sound pressure levels and the measured sound pressure levels can be attributed to ground and environmental effects. Results from Site 1 are provided in Figure 5. The significant observation is that there is little variance in the lower frequency ranges (100-600 Hz) across all of the measured soil moisture and ground hardness measurements for that location.

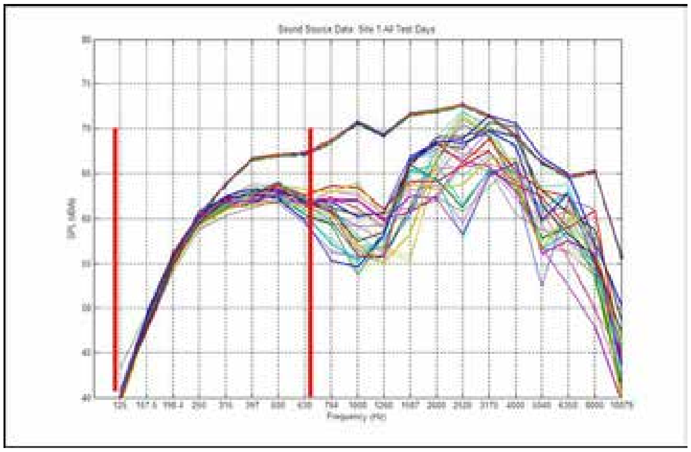

Figure 5: Sound Source Data: Site 1 All Test Days

Typical sound source test results for different test locations are presented in Figure 6. Frequencies of interest in the snowmobile testing are in the 100-600 Hz range, where a large amount of variability is observed from site to site.

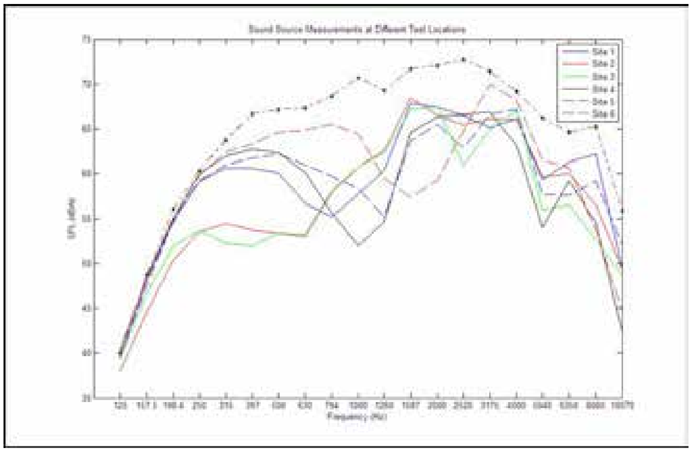

Figure 6: Sound Source Measurements at Different Test Locations

These data suggest that the soil moisture or ground hardness levels alone are not a dominant factor in the sound propagation at different test locations. However, these data suggest that soil type is a dominant factor in the same frequency region where snowmobiles operate. It is noted that soil types can vary greatly from region to region and the data shows that sound propagation has different trends at different test locations. The ability to measure soil moisture at each location was critical in making the conclusion that soil type is more critical than just soil moisture or ground hardness alone.

References:

SAEJ192, 2004, Maximum Exterior Sound Level for Snowmobiles

Lord, H., William, G., Evensen, H., 1980, Noise Control for Engineers, Krieger Publishing Company.