C48 Uncertainty Issues in Tribometric Testing: Isolating the Contribution of the Tribometer

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After attending this presentation, attendees become familiar with the concept of measurement uncertainty, and how it differs from error; how uncertainty is an aggregate function of the many individual sources of measurement uncertainty, and how measurement uncertainty relates to tribometric testing in Walkway-Safety analyses.

This presentation will impact the forensic community and/or humanity by demonstrating how the fact that the noise inherent in tribometric testing is not due to the fact that the testing instrument is in some way problematic implies that standard statistical measures should be able to address the variability. (That's the Good News.) The Bad News is that sample sizes larger than often used in WSTT may well be required, which would certainly add to the cost of such testing.

Tribometric testing in the field of Walkway-Safety is the testing of the friction between a walkway surface (or a walkway-surface surrogate, called a *test surface*) and a shoe bottom (or shoe-bottom surrogate, called a *test foot*). There is significant controversy concerning the very appropriateness of walkway-safety tribometric testing (WSTT), where opinions range from—on one hand—tribometric testing is no different than measuring a voltage using a voltmeter, to—on the other—that tribometric testing is worthless and cannot come close to meeting the scientific certainty required to pass the Daubert threshold. In a related controversy, some, for various reasons, refuse to characterize the numeric results from WSTT as coefficients of friction, rather, referring to the results as *slip-resistance* coefficients. What is remarkable indeed about those who engage in this (and we're being charitable here) debate is the complete lack of empirical or theoretical justification for the positions taken; the debate is more akin to a theological, T-shirt wars dispute rather than something based upon scientific or engineering evidence.

The essential argument of those who argue the position that Walkway-Safety tribometric testing is worthless (the folks with **NO** boldly printed on their T-shirts) is that the testing of the friction between the walkway shoe surfaces is so noisy, i.e., unreliable, that the results cannot get over the scientific-certainty threshold. The least dogmatic of the **NO** group argue that protocols and procedures are not yet refined enough to be scientifically certain, and that, over time, and with work and luck, WSTT can be expected to take its place in the armamentarium of Walkway-Safety analysts. The most dogmatic of the **NO**'s argue that the very notion of measuring friction between two surfaces separated by a liquid at their interface, modeling a person walking on a wet floor, is inappropriate because "the slip resistance of a floor when wet is unknown and unknowable."[1]

The authors have been and are involved in rigorously characterizing the response of a specific tribometer, i.e., the Slip-Test PIAST using experimentation and logistic regression. The results of that work appear in a separate paper. This paper places that work in the broader context of WSTT.

Measurement Uncertainty in WSTT stems from a number of factors, some of which may be correlated. Some of the more significant factors are the variability from point to point in the floor (or test surface), the variability in the shoe bottom (or test foot)—either from shoe bottom to shoe bottom or over time), the variability in any contaminant (either composition or quantity), and the variability of the tribometer itself. If the variability of the tribometer were a significant component of total uncertainty, this would complicate the measurement process.[2]

Experiments using the PIAST conclusively show that, at least with respect to the PIAST, the measurement uncertainty inherent in the instrument is a relatively small factor in the total uncertainty inherent in tribometric testing. In other words, it seems that the variability observed in WSTT stems from the fact that the authors were observing a noisy process, and not because the tribometer itself is problematic.

References:

[1] While the position of the former group is, at least, arguably correct, the position of the latter is incorrect on its face. If wet-surface friction measurement is (a) inherently "unknown and unknowable," then one could mot measure the friction of an oil-lubricated crankshaft (something that's been routinely accomplished for generations); if (b) some wet-surface phenomena (like the frictional resistance of a crankshaft spinning in oil-lubricated bearings) is measurable and some (like a pedestrian walking on a wet surface) are not, then those taking the position are incorrectly asserting that the difficulties in measurement are impossible to overcome, making a question of *degree* into a question of *kind*. In short, even if (and the authors do not agree with this position), how to measure wet-surface friction is perhaps *unknown*, that cannot imply that it is *unknowable.*

[2] The uncertainty of a measurement process is often characterized by its Standard Deviation. For example, if a quantity *Y* is a function of a set of variables $\{x_1\}$:

$$Y = f(x_1, \ldots, x_n)$$

where component *i* has the (typical) mean and standard deviation)

$$\overline{X}_i = \frac{1}{n}\sum_{k=1}^{n} x_{ik}$$

$$s_{\overline{X}_i} = \sqrt{\frac{\sum_{k=1}^{n}\left(x_{ik}-\overline{X}_i\right)^2}{n(n-1)}}$$

then, depending upon the structure of $f(x_i)$, the aggregate Uncertainty can be found. For the simplest case, if the *n* variables are uncorrelated and in linear combination:

$$y = a_1 x_1 + a_2 x_2 + \ldots a_n x_n$$

then the Aggregate Uncertainty, again assuming that the Uncertainty of the ith component can be characterized by the Standard Deviation of it's
Average, then

$$u_{aggregate}(y) = \sqrt{\sum_{i=1}^{n} a_i^2 s_{\overline{X}_i}^2}$$

More complex situations, including correlation between factors, can be addressed by using a Taylor-series approximation.
(See http://physics.nist.gov/cuu/Uncertainty/combination.html):

$$u_{aggregate}(y) = \sqrt{\sum_{i=1}^{n}\left(\frac{\partial f}{\partial x_i}\right)^2 u^2(x_i) + 2\sum_{i=1}^{n-1}\sum_{j=i+1}^{n}\frac{\partial f}{\partial x_i}\frac{\partial f}{\partial x_j}u(x_i, x_j)}$$

Uncertainty Analysis, Tribometric Testing, Forensic Engineering

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