Summary of Research Results

Steven D. High, MS, CSP, ARM, CXLT
High Safety Consulting Services, Ltd.
717-293-4483

While the intent of this study was to explore the possibility of defining a correlation between residence time and sticktion forces, no significant correlation between these two variables was able to be demonstrated in these tests.

Sticktion is identified in most literature to be a function of residence time. Yet no study found in the review of literature attempts to define this function specifically. It was the intent of this study to control many of the standard variables (test foot material, flooring surface, operator technique, drag rate, foot test pressure, humidity, temperature) while varying residence time. The results of the experimental drag-sled tests can not correlate or define residence as a function of sticktion. The data does demonstrate that wet surface testing with a drag-sled device results in erroneously higher readings, although this is not new information.

There is an assumption by many that by applying a horizontal and vertical force simultaneously sticktion can be overcome or avoided using a drag-sled type tribometer. The testing device developed for this research actuated in less than 16 ms, yet the slip-resistance reading in a wet condition was still higher than the same measurement taken in a dry state. This was also demonstrated in Irvine's 1986 study wherein he had

modified the actuation method of his drag-sled device, so that a wet reading could be obtained within 3.3 seconds of contact.

Since there is significant variation in the performance of leather and the fact that leather is known to change its characteristics over time in a wet state, we can review the non-leather material results of Irvine's study. In these tests, very little variation is shown between wet and dry state tests. In fact, most of the test results with test materials demonstrated slightly higher readings in a wet state. Since the materials used were terrazzo and vinyl asbestos, it is inconsistent with common knowledge regarding these materials to expect a greater slip-resistance when wet.

In addition, William English's attempt to develop a quick actuating drag-sled tribometer was abandoned when the residence time of 250 ms was determined to be the reason why the device was not providing valid readings on wet surfaces.

With all of these efforts at overcoming sticktion with a drag-sled approach, it brings into question if a drag-sled device could ever be designed that would overcome the effects of sticktion. Perhaps it is not the residence time of the test as much as it is the validity of applying this approach to wet testing. A drag-sled device certainly does not emulate human ambulation and perhaps this traditional method of assessing slip-resistance can not be applied in wet surface testing for reasons other than residence time.

In a human slip event velocity increases as the slip progresses. A static drag-sled device does not reproduce this motion. Changes in slip resistance may not be significantly affected by velocity with certain testers, but the rate of acceleration can be a factor in causing a peak force meter to read high. The hydraulic design of the test instrument allowed for a constant velocity with a fixed acceleration, which can not be maintained with drag sleds that depend on manual operation as required in the ASTM C-1028 test method for evaluation of ceramic flooring and similar surfaces.

Future Research

The wide variability in test results of the experimental tester in this study resulted in an inability to evaluate the intended study topic of residence effects on sticktion. Modifications to the tester could be made to improve the ability to obtain more consistent and reliable results.

These changes could include increasing the weight of the test foot. Many of the drag-sled devices in operation today which have some validation of their results utilize a heavier drag weight. The ASTM C-1028 method uses a user-constructed drag-sled that incorporates a fifty pound weight. The Portable Inclinable Articulated Strut Tester (PIAST) referred to as the Mark II uses a ten-pound weight and the James Machines under ASTM F 489 uses a hefty eighty-pound weight. The lightest of the recognized test methods was the HPS which weighs in at six pounds. By

comparison the experimental drag sled used in this study had a weight range between 0.598 pounds up to 0.849 pounds.

While Amontons-Coulomb's classical theory of friction hypothesizes that friction is independent of contact pressure, the lighter weight may have had a negative impact on the ability to measure the relatively small sticktion forces. In Marpet and Brungraber's (1996) study the effect of contact pressure was significant but had only a slight impact on the results of the testing. It is also unknown as to the effect a heavier weight may have on the stick-slip phenomenon that was observed in some of the tests. When this effect was observed, the test results were excluded from the data.

Increasing load weight may also require that the test foot be enlarged for stability. Downward torsion into the test surface was observed with the 1 ¼" diameter Neolite® test foot in some tests. This seemed to be related to the angle of the pull relative to the test surface. The test foot is identical to the test foot used by the English XL and was selected so that correlations to the English XL would be more likely. The greater the pressure on this small test foot, the more likely the weight will need to be distributed further and further from the center and more likely the test foot will be subject to lever effects of the additional weight.

The other modification which is related to the weight and the surface area of the test foot is the contact pressure. The small test foot

and light weight used resulted in a pressure range of 0.49 p.s.i. to 0.69 p.s.i. This is well under the typical walking pressures which can exceed 1000 p.s.i. at heel strike at the upper end (Marpet, 1996).

There are also significant peak force meter variations when a force is applied at an angle other than 90 degrees. This variation was controlled by visually checking the alignment of the meter extension bar. By creating a fixed mounting tray which is adjustable in the y-axis, the z-axis could be fixed and the potential for an angled pull would be reduced.

In terms of design, a retractable hydraulic system would allow for a faster testing sequence. In the current design, the system pressure must be zeroed and the hydraulic cylinders need to be manually returned to their closed position. Alternations in these aspects could allow for the system to hold pressure for multiple tests.

This experiment could also be repeated with a modified and validated slipmeter which is altered to allow for the hydraulic actuation via electrical signal control.

Currently, many tribometrists discuss the role sticktion plays in measuring wet surfaces. There is general acceptance that sticktion is a function of residence time. This study was unable to demonstrate a relationship. To date, no researcher (known to this author) has been able to define the relationship between sticktion and residence time mathematically in a controlled testing environment. The relationship

between these two variables is a very complex one that may be multi-variant with any number of other factors ranging from molecular structure interactions to surface deformation to Schallmach wave theory.

Perhaps sticktion is not a function of residence time with rubber-based sliders and in fact may be a phenomenon of all wet testing using drag-sleds, regardless of residence. This study and Irvine's study would support this as a possibility. Sticktion does seem to be a factor and connected with residence with leather-based sliders in Irvine's results. The same connection is not observed with rubber-based sliders. This is probable as the leather is more apt to change characteristics over time and as it is exposed to moisture. So while sticktion may be a function of residence time in leather sliders, it may be unrelated to residence time with rubber-based test feet. In drag-sleds equipped with rubber-slider, it may be possible that sticktion is simply inherent in the test method and is not connected to residence time as is the common convention.