2-2011

Validation of Proposed Metrics for Two-Body Abrasion Scratch Test Analysis Standards

Ryan L. Kobrick
University of Colorado Boulder, kobrickr@erau.edu

David M. Klaus
University of Colorado Boulder

Kenneth W. Street
NASA Glenn Research Center

Scholarly Commons Citation

Kobrick, R. L., Klaus, D. M., & Street, K. W. (2011). Validation of Proposed Metrics for Two-Body Abrasion Scratch Test Analysis Standards. , (). Retrieved from https://commons.erau.edu/publication/537

NASA/TM—2011-216940

Validation of Proposed Metrics for Two-Body Abrasion Scratch Test Analysis Standards

Ryan L. Kobrick and David M. Klaus
University of Colorado at Boulder, Boulder, Colorado

Kenneth W. Street, Jr.
Glenn Research Center, Cleveland, Ohio

February 2011

NASA STI Program . . . in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA Scientific and Technical Information (STI) program plays a key part in helping NASA maintain this important role.

The NASA STI Program operates under the auspices of the Agency Chief Information Officer. It collects, organizes, provides for archiving, and disseminates NASA's STI. The NASA STI program provides access to the NASA Aeronautics and Space Database and its public interface, the NASA Technical Reports Server, thus providing one of the largest collections of aeronautical and space science STI in the world. Results are published in both non-NASA channels and by NASA in the NASA STI Report Series, which includes the following report types:

- TECHNICAL PUBLICATION. Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.

- TECHNICAL MEMORANDUM. Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.

- CONTRACTOR REPORT. Scientific and technical findings by NASA-sponsored contractors and grantees.

- CONFERENCE PUBLICATION. Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or cosponsored by NASA.

- SPECIAL PUBLICATION. Scientific, technical, or historical information from NASA programs, projects, and missions, often concerned with subjects having substantial public interest.

- TECHNICAL TRANSLATION. English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services also include creating custom thesauri, building customized databases, organizing and publishing research results.

For more information about the NASA STI program, see the following:

- Access the NASA STI program home page at *http://www.sti.nasa.gov*

- E-mail your question via the Internet to *help@sti.nasa.gov*

- Fax your question to the NASA STI Help Desk at 443–757–5803

- Telephone the NASA STI Help Desk at 443–757–5802

- Write to:
  NASA Center for AeroSpace Information (CASI)
  7115 Standard Drive
  Hanover, MD 21076–1320

NASA/TM—2011-216940

Validation of Proposed Metrics for Two-Body Abrasion Scratch Test Analysis Standards

Ryan L. Kobrick and David M. Klaus
University of Colorado at Boulder, Boulder, Colorado

Kenneth W. Street, Jr.
Glenn Research Center, Cleveland, Ohio

National Aeronautics and
Space Administration

Glenn Research Center
Cleveland, Ohio 44135

February 2011

Acknowledgments

This research was supported by a NASA Graduate Student Researchers Program (GSRP) grant (NNX07AR55H) provided by the Dust Management Project, under the Exploration Technology Development Program. Matlab assistance was provided by Kevin Higdon, Ph.D. Candidate (UCB) and Bradley W. Cheetham, Ph.D. Student (UCB). Test equipment and support were provided by NASA Glenn Research Center. Additional support was provided by BioServe Space Technologies (UCB) and the Achievement Rewards for College Scientists (ARCS) Foundation, Inc.

Level of Review: This material has been technically reviewed by technical management.

Available from

NASA Center for Aerospace Information
7115 Standard Drive
Hanover, MD 21076–1320

National Technical Information Service
5301 Shawnee Road
Alexandria, VA 22312

Available electronically at http://www.sti.nasa.gov

Validation of Proposed Metrics for Two-Body Abrasion Scratch Test Analysis Standards

Ryan L. Kobrick and David M. Klaus
University of Colorado at Boulder
Boulder, Colorado 80309

Kenneth W. Street, Jr.
National Aeronautics and Space Administration
Glenn Research Center
Cleveland, Ohio 44135

Abstract

The objective of this work was to evaluate a set of standardized metrics proposed for characterizing a surface that has been scratched from a two-body abrasion test. This is achieved by defining a new abrasion region termed "Zone of Interaction" (ZOI). The ZOI describes the full surface profile of all peaks and valleys, rather than just measuring a scratch width as currently defined by the ASTM G 171 Standard. The ZOI has been found to be at least twice the size of a standard width measurement, in some cases considerably greater, indicating that at least half of the disturbed surface area would be neglected without this insight. The ZOI is used to calculate a more robust data set of volume measurements that can be used to computationally reconstruct a resultant profile for detailed analysis. Documenting additional changes to various surface roughness parameters also allows key material attributes of importance to ultimate design applications to be quantified, such as depth of penetration and final abraded surface roughness. Data are presented to show that different combinations of scratch tips and abraded materials can actually yield the same scratch width, but result in different volume displacement or removal measurements and therefore, the ZOI method is more discriminating than the ASTM method scratch width. Furthermore, by investigating the use of custom scratch tips for our specific needs, the usefulness of having an abrasion metric that can measure the displaced volume in this standardized manner, and not just by scratch width alone, is reinforced. This benefit is made apparent when a tip creates an intricate contour having multiple peaks and valleys within a single scratch. This work lays the foundation for updating scratch measurement standards to improve modeling and characterization of three-body abrasion test results.

1.0 Introduction

A key physical property associated with lunar regolith (as well as regolith from other extraterrestrial destinations) is its abrasive quality. Abrasion of mechanical components and fabrics by soil on Earth is typically minimized by the effects of atmosphere and water eroding sharp and pointed geometrical features from potential abrasive particles. In environments where these erosive forces do not exist, such as the vacuum of the Moon, particles retain geometries associated with fracturing of their parent particles by micrometeorite impacts. The relationship between hardness of the abrasive and that of the material being abraded is well understood, such that the abrasive ability of a material can be estimated as a function of the ratio of the hardness of the two interacting materials (Ref. 1). Applying this relationship to the lunar mineral composition, one would expect the Moon to have modest abrasive ability, considering that many of the lunar particles also have sharp edges and points (Ref. 2).

Similar analogies can be made with regard to the particulate toughness, although direct correlation between lunar and terrestrial mineral counterparts has recently come into question (Ref. 3). Recent discoveries in lunar geology indicate that the Moon is not as homogeneous as previously thought; therefore, a simple generic Mare and Highlands regolith composition may no longer be realistic. Instead, there may be vast regions of interest where the composition is nearly pure spinel, which is considerably harder than the bulk constituents of either Mare or Highland material (Ref. 4). Hence, our interest in fabricating custom scratch tips for use in fundamental abrasion studies for lunar and other extraterrestrial exploration systems are growing. When changing tip materials and geometries, the standard scratch test method based on scratch width alone leaves much to be desired, as it ignores a considerable amount of information associated with a scratch, such as material removal versus displacement and the magnitude of the actual region of interaction in the test material.

This paper is a continuation of prior work that proposed a set of standardized volumetric displacement metrics for analyzing two-body abrasion scratch test results (Ref. 5). Technology limitations were identified in the current ASTM G 171 Standard for scratch testing (Ref. 6), which specifies scratch width as the key measurement. The development of new imaging capabilities that allow a complete profile to be characterized in a three-dimensional array was suggested to enable a more detailed analysis of the scratched surface. Table 1 summarizes the proposed new standard attributes. A "Zone of Interaction" (ZOI) was defined to characterize the entire abrasive wear area, including volumes outside of the scratch width boundaries, as indicated in Figure 1. Two scratches with the same width do not necessarily have the same ZOI. This follow on work includes quantitative results obtained using the earlier developed protocol (Ref. 5) to demonstrate the benefit of updating the current standard with the enhanced three-dimensional volumetric measurements that are now achievable.

TABLE 1.—SUMMARY OF IMPROVEMENTS TO CURRENT SCRATCH STANDARD

Current standard (ASTM G 171 properties)	Identified limitations for current ASTM G 171	Proposed new standard
Manual measurements by optical investigation	Measurement errors/variations one-dimensional	Three-dimensional profile generation by optical interferometery
Scratch width is key variable	Volume not considered	Total volume and surrounding area (ZOI)
Determination of width boundary conditions	Random boundary placement for width measurement on fringes	Knowledge of width location not required
Diamond tip stylus	Limited testing scenarios	Application specific tip materials Ex. Lunar mineral tips demonstrated

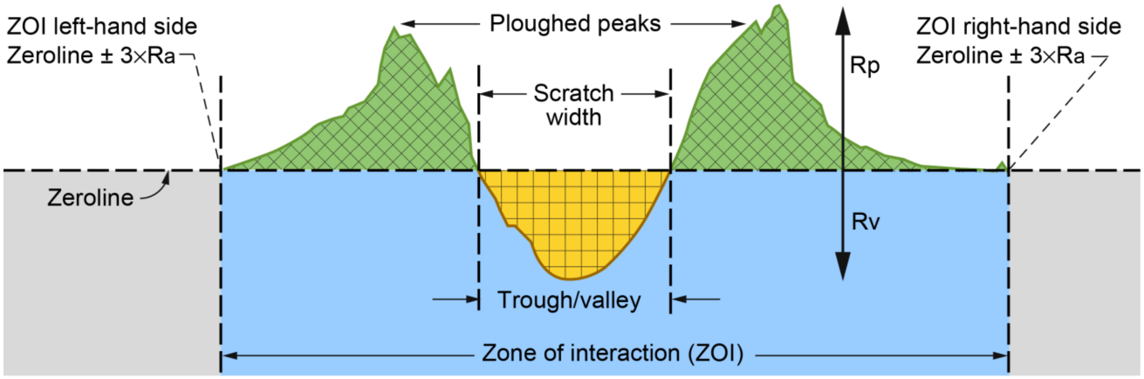


Figure 1.—Example of boundary conditions for zone of interaction at ± 3×surface roughness (Ra) showing negative and positive displacements.

The standard roughness parameters, which complement the new proposed metrics and help define the material surface before and after abrasion include: surface roughness (Ra); root-mean squared roughness (Rq); maximum depth of penetration or deepest point (Rv); maximum displaced height or highest point (Rp); peak-to-valley difference (Rt = |Rp| + |Rv|); and average ten greatest peak-to-valley Separations (Rz) (Ref. 7). Rq and Rz are included in the calculations in this paper because they are part of an industry standard set that may be used in future work.

The proposed metrics defined in Table 2 use the ZOI to normalize a scratch volume and the length of the scratch scanned in each profile (not complete scratch length) yielding units of µm. The surface roughness parameters are referred to as Metric Set B, and include initial measurements on the polished material and final conditions bounded by the ZOI (units are µm for all six values).

TABLE 2.—PROPOSED METRICS NORMALIZED BY ZOI AND SCAN LENGTH

Metric	Description	Formula, µm
A1	Negative displaced metric	$\frac{\text{Negative volume displaced}}{\text{ZOI}_{\text{Average}} \times \text{Scratch scan length}}$
A2	Positive displaced metric	$\frac{\text{Positive volume displaced}}{\text{ZOI}_{\text{Average}} \times \text{Scratch scan length}}$
A3	Net displaced metric	A1 + A2
A4	Absolute displaced metric	|A1| + |A2|

2.0 Materials and Methods

All two-body abrasion scratches were made using a CSEM (now CSM Instruments, Neuchatel, Switzerland) Revetest automatic scratch tester CH-2000 Neuchatel 7 (FR-A 121) per ASTM G 171 guidelines (Fig. 2). In the scratch tester, a material specimen is horizontally translated at a controlled speed while a stationary diamond tip stylus is applied vertically under a specified normal load. For this study, a variety of tip sizes with differing mineralogy were examined on typical spacecraft materials to investigate the potential abrasive wear from lunar dust for surface exploration design applications.

Aluminum (Al) 6061-T6 and stainless steel 304 were used as two common spacecraft material specimens. Each sample was polished with 1 µm alumina powder and water on a polishing wheel to remove minor surface imperfections and even out any material thickness differences. Polycarbonate with titanium dioxide (TiO_2) coating is typically used for spacesuit helmet visors and represents another critical application-driven material to characterize. The two diamond tips used for scratch tests are defined by their radius dimension of either 200 or 109 µm, both with a 120° apex tip angle. Custom tips were fabricated out of mineral counterparts or analogues that are expected to be similar to lunar mineralogy. Discussion of these custom tips is limited to demonstration purposes here, but it was due to the need for these tips and their corresponding irregular scar volumes that an alternate method of measuring abrasion was sought.

For each tip and specimen material combination, three independent scratches were conducted. Each scratch was then profiled three times using Veeco Instruments Inc.'s NT-1000 optical interferometer and WYKO Vision32 software for NT-2000. The Veeco measurement includes 480 cross sections, which is a sufficiently larger than the standard three-width measurements in ASTM G 171. A code was developed in MATLAB (Mathworks, Inc. software) to measure the key parameters noted above and to calculate the indicated metrics based on the three-dimensional data array outputted from the Veeco equipment. During coding, several computational challenges were encountered, including correction for minor tilt variations in the specimens; proper edge detection of the ZOI that avoided false boundaries from small material divots; and tuning the sensitivity of the boundary condition limits using the surface roughness as specified in Figure 1. Since the goal of this research was to provide a guideline for standardization measurements

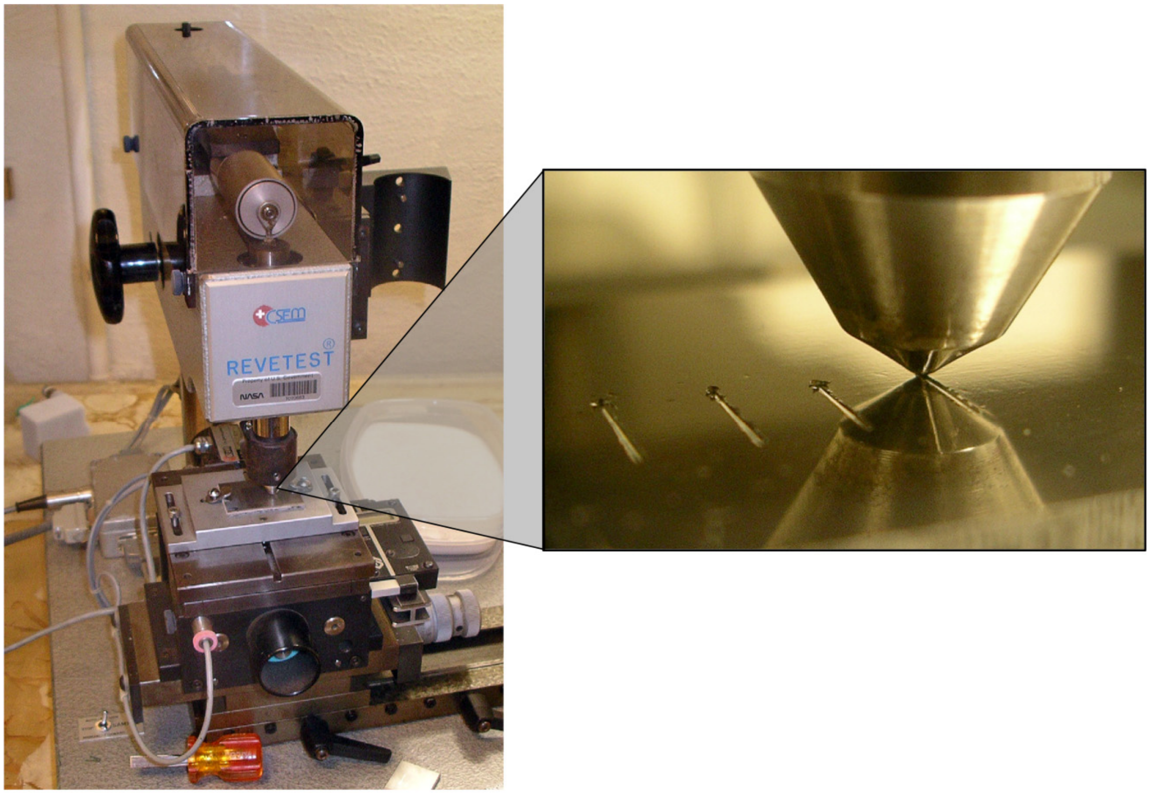


Figure 2.—Revetest scratch tester showing close-up of a diamond tip scratching an aluminum specimen.

and not to deliver a user-ready software package and since these issues were somewhat unique to test circumstances and were resolved for our purposes, they are not further described here. They do, however, warrant mention to avoid being overlooked in future application of this technique by others.

3.0 Reconstruction of an Average Surface Profile From Metrics

Taking the output metrics from actual data and being able to reconstruct the original conditions can evaluate the robustness and quality of a set of metrics. To assess the quality of the four proposed “A” metrics defined above, a subset of data was tabulated from nine profiles. The nine profiles included three consecutive scratches with three Veeco profiles generated from each scratch. The test conditions involved a diamond 200 µm radius (120° apex angle) tip on aluminum 6061-T6 with an 80 N normal load during each scratch. Measurements were made using two different MATLAB codes to obtain the ZOI, scratch width specified by ASTM G 171 (the width boundary end points were located at the Zeroline location on the displaced slopes as seen in Fig. 1), and the four “A” metrics.

The data were averaged for these nine profiles to produce a scratch ZOI of 575±47 µm, a width of 325±16 µm, A1 of –44 µm, A2 of 21 µm, A3 of –23 µm, and A4 of 64 µm. These average values for ZOI and width were used to recreate a profile as illustrated in Figure 3, demonstrating the ability to restructure an X-Y view (top of surface) from test data. One of the nine profiles was placed under the gridlines in Figure 3 to show how the averaged values map back to the original data. Likewise, a vertical scale reconstruction can be achieved with the set of “A” metrics as displayed in Figure 4. A1 specifies how much material is within the scratch valley, while A2 indicates the displaced volume. The difference, A3, is the volume balance, which in this case, shows that material was removed in the average of the nine profiles. A4 gives us the magnitude within the ZOI from peak to valley. The surface roughness parameters can be used similarly within the ZOI, but they do not indicate the volume balance between removed and displaced.

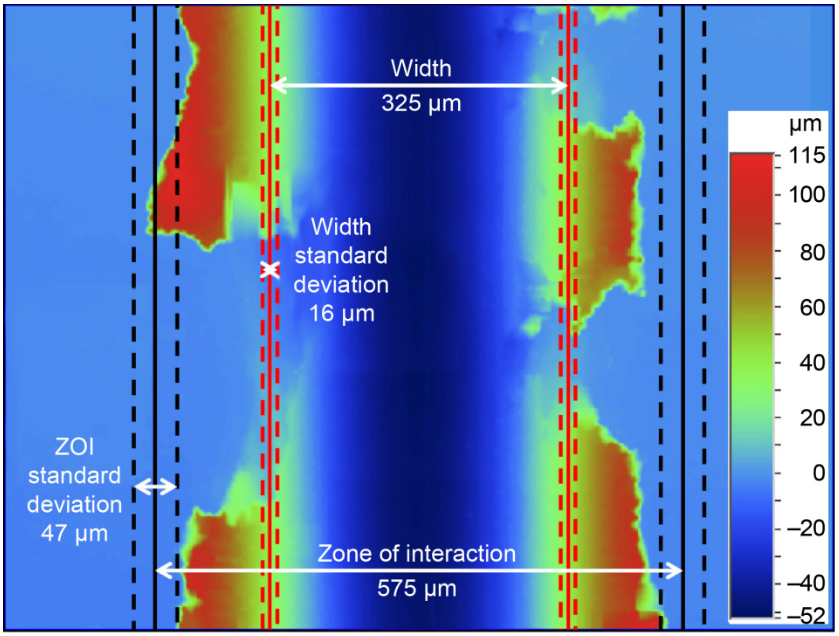


Figure 3.—Average ZOI and width values from nine scratches overlaid on one sample to recreate a scratch profile.

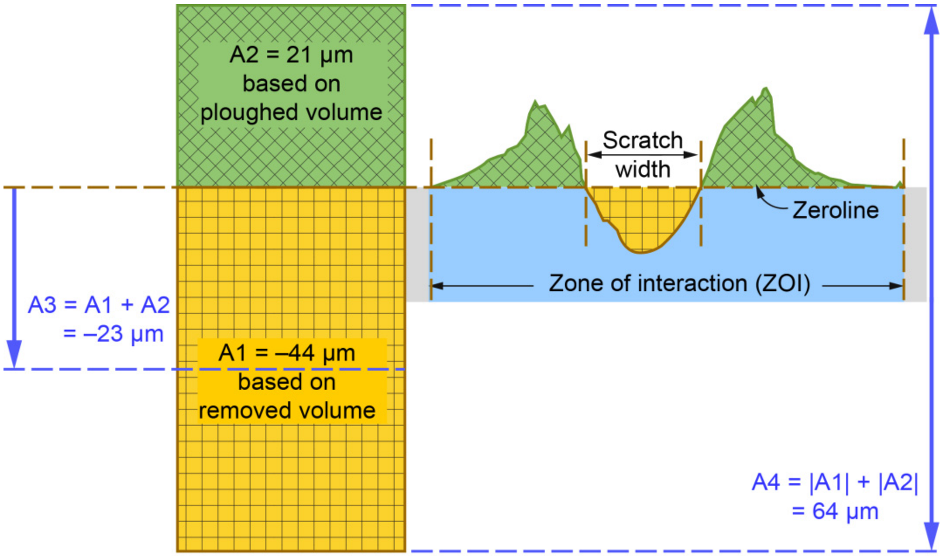


Figure 4.—Average "A" metric values from nine scratches summarized visually showing volume balance of material removed (A1) versus ploughed (A2) on a vertical scale.

4.0 Results and Discussion

To further evaluate the robustness achieved by characterizing these new metrics compared to using width alone, a case study using three different tip-to-material combinations that produced the same scratch width was analyzed. The case study examines the volumetric "A" values as well as the surface roughness parameters. The ZOI is compared to scratch width versus a range of normal applied loads for two different diamond tip dimensions, including the depth of penetration data and a brief discussion of custom tip applications.

4.1 Case Study: Same Width Scratches With Different Volumes

To contrast these new metrics with results based on the current ASTM G 171 Standard that uses width to calculate abrasion properties, three profile cases were found in the research database with virtually the same scratch width (207 µm), but with different volumetric profile properties. Figures 5 and 6 summarize the three different profiles and key test and data parameters including scratch tip, abraded material, applied normal load, width (as estimated using ASTM G 171), ZOI, "A" metric, and surface roughness parameters (Ra, Rq, Rv, Rp, Rt, and Rz). The cases are pictorially ordered by decreasing ZOI, while scratch width remains essentially constant.

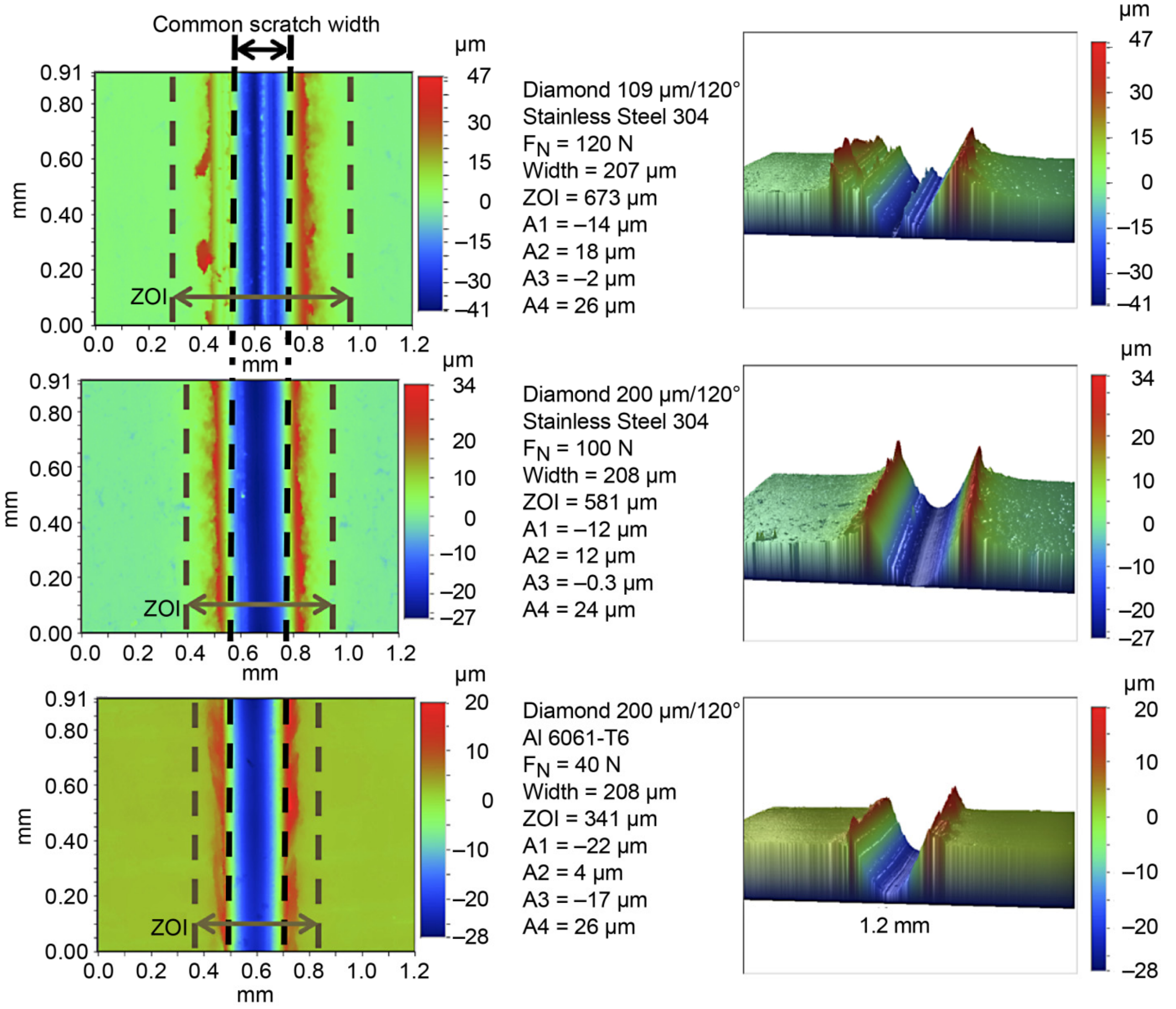
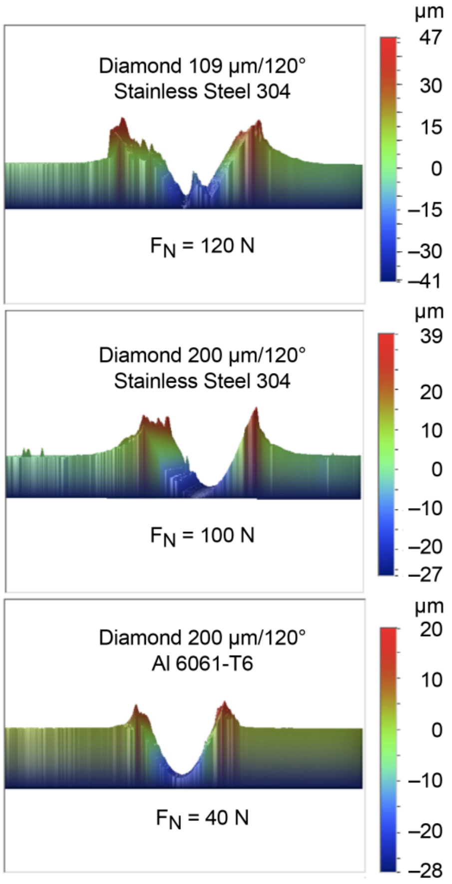


Figure 5.—Three profiles that have the same resultant width measurements, but are distinguishable by their different volume displacement metrics.



Parameter	Polished zone, µm	Zone of interaction, µm
Ra	0.22	13.3
Rq	0.32	17.1
Rv	–3.25	–40.5
Rp	0.79	46.5
Rt	4.03	87.0
Rz	3.74	86.3

Parameter	Polished zone, µm	Zone of interaction, µm
Ra	0.23	11.9
Rq	0.38	14.5
Rv	–3.79	–26.5
Rp	0.82	33.8
Rt	4.61	60.3
Rz	4.41	59.8

Parameter	Polished zone, µm	Zone of interaction, µm
Ra	0.12	12.0
Rq	0.16	13.1
Rv	–0.72	–27.6
Rp	0.55	19.6
Rt	1.27	47.2
Rz	1.15	46.8

Figure 6.—Roughness parameter data for three profiles with the same width measurements.

The three cases contain a diverse sampling pool of variables and tip to material combinations including applied load, scratch tip dimensions, and material abraded. The case study results illustrated in Figure 5 show that if just the width were measured for all of these cases, they would appear identical. However, it is apparent that the ZOI is significantly larger than the width for all cases, but using the current standard this extended region of material deformation would be neglected. Furthermore, for the stainless steel cases, material has mostly been displaced (A3 is close to zero), but for the aluminum it has been removed (A3 is largely negative). Being able to characterize this additional information is important because it can be correlated to potential mass changes of a system or severity of abrasion. For example, this could be critical if the center of mass changes for a surface vehicle. Finally, while the peak-to-valley volume change (A4) in all cases is similar, the normalized volume removed (A1) is almost double for the aluminum and the normalized displaced volume (A2) is three times as great for the steel sample. This case study shows that the actual differences in the material would not be discernable if width measurement alone were used and therefore reinforce the need to analyze the entire ZOI while making abrasion measurements. The "A" metrics provide an overview of the abrasion that has occurred to produce a comprehensive surface analysis.

The roughness parameter data in Figure 6 shows the overall change in material shape from abrasion. The roughness (Ra) and root-mean-squared (Rq) values are all similar, but the valley depth of penetration (Rv) and max ploughed peak (Rp) values are unique. The new proposed metrics combined with the surface roughness parameters are designed to remove shape dependency of the abrasion tip, which the old standard does not address. Penetration depth is of particular importance for materials that may have a critical surface coating. For example, an astronaut's helmet visor has antiglare and UV protective coatings; if these become abraded, protection is reduced and vision becomes obscured, as was reported during the Apollo missions (Ref. 8).

4.2 Comparing Zone of Interaction to Scratch Width

In all cases explored in this research, the ZOI was observed to be at least twice as wide as the ASTM G 171 Standard specified scratch width. This further indicates that most of the scratch zone is not accounted for in previous studies using width as the key metric. To demonstrate the magnitude difference, the ZOI and width results from all stainless steel scratch profiles created by both diamond tip dimensions (109 and 200 μm radii) are plotted in Figure 7. A polynomial fit of the data shows R-squared correlations closer to 1 than linear trends, suggesting that the relationship between load and scratch interaction may not be linear as indicated by the scratch hardness number formula specified in the ASTM G 171 Standard (Ref. 6). These non-linear trends were also seen in other data acquired for various tips and abraded material combinations. The variability that is shown in the ZOI in Figure 7 is attributed to the dynamically changing abrasion boundaries of the actual material along the length of the scratch.

Another observation from Figure 7 is that the different sized diamond tips produced similar results for ZOI and scratch width, but penetration depth varied. If only width was used to analyze the abrasion caused by these two tips, then a conclusion may be inferred that there is not a significant difference in the interaction. If we look more closely at final depth of penetration (Rv), however, we see that sharper 109 μm radius diamond tip is more than 10 μm deeper for every load combination on stainless steel 304 (Fig. 8) than the 200 μm radius tip. The initial penetration depth data is included in Figure 8 to show that even the polished portions of the stainless steel 304 specimens have divots as deep as –14 μm, which means in some materials there will be outlier locations that may skew the comparison of before to after data. Other output data for the stainless steel 304 not presented here shows that the volume removed (A1) and displaced (A2) for both tips are similar. Because of the similar width, ZOI, and volume measurements, measuring roughness parameters such as Rv is necessary to ensure limits for material coating penetration are not exceeded.

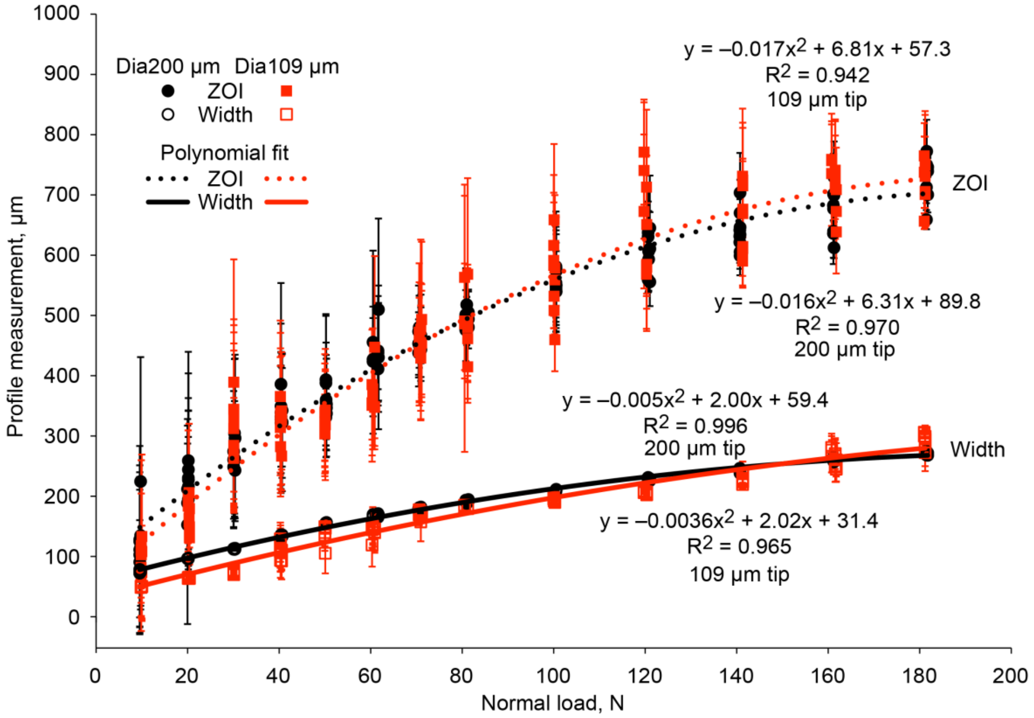


Figure 7.—ZOI and width measurements from two different diamond tips abrading stainless steel 304.

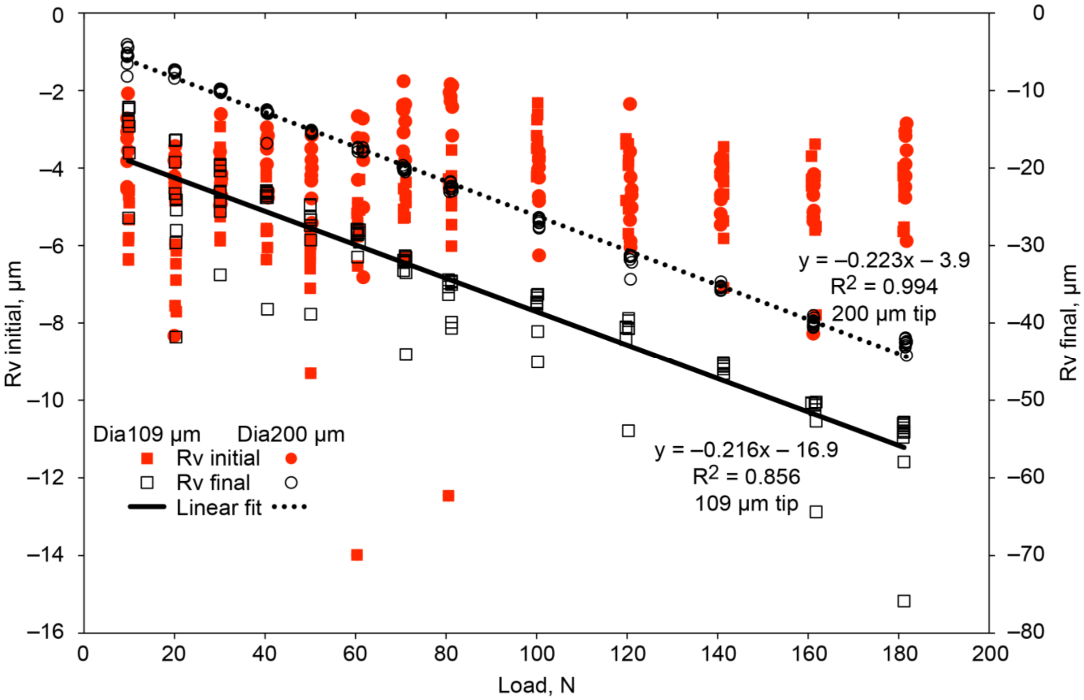


Figure 8.—Depth of penetration (Rv) from two different diamond tips abrading stainless steel 304.

4.3 Custom Tip Sample Data

For our application purposes, custom scratch tips were created using minerals similar to those that are expected to be encountered on the Moon. As a consequence of the irregular tip shapes and orientations, multiple peaks and valleys were produced along a single, continuous scratch. This observation made it apparent that width alone was insufficient to fully characterize the end result on the material and led to the definition of the proposed new suite of metrics. In addition, when custom tips were used, it was observed that the load applied to the mineral tip was more critical than its shape, as friable minerals would often shatter and cause multiple, parallel scratches during the test. An example of a typical scratch that might be expected to occur on lunar surface equipment during actual use is shown in Figure 9. The material interaction resulted from using a custom enstatite tip (Fig. 10) on Al 6061-T6 with a 10 N applied normal load. The irregularity of the tip shape is intended to be more representative of actual lunar dust, thus produce operationally relevant abrasion. The finding of large areas of the lunar surface primarily composed of spinel indicates that even what are traditionally understood as trace minerals may be more important to test. Spinel is extremely hard and expected to be an important abrasive if found in high concentrations.

Recently available information on the strength of lunar regolith grains as compared to terrestrial materials of similar composition further friability concerns. Cole (Ref. 3) has demonstrated that lunar plagioclase grains can have two to three times less mechanical strength than terrestrial material when compressed. Inspection of Figures 1 and 2 of Cole's paper clarifies why the terrestrial counterparts are considerably more robust. In the figures, the lunar grains appear to be composed of much smaller fragments fused or sintered together. This structure is considerably weaker at the fragment boundaries than the internal crystal energies holding mineral crystals grains together thus leading to their enhanced friability. Should lunar grains be applied to the testing procedure described in section 2.0 of this paper, one would expect to see progressive damage to the tip along the entire length of the scratch resulting in a profile beginning as shown in Figure 6 (top frame) and ending as shown in Figure 9. Measurement of scratch width according to ASTM G 171 would be impossible in such a situation; however, for the profilometry method proposed herein, it would be straightforward to identify profile metrics along the length of the scratch for diagnostic and reconstruction purposes.

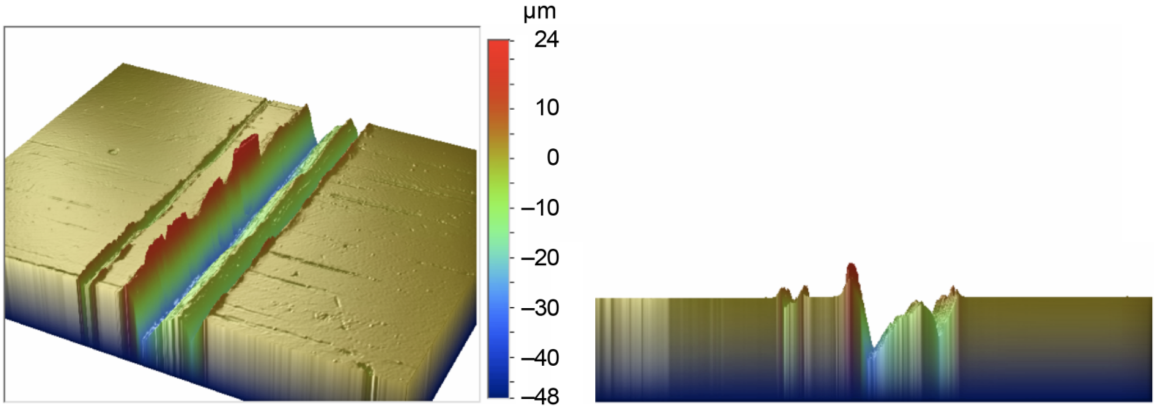


Figure 9.—Al 6061-T6 profile created from custom enstatite tip with 10 N applied load.

Figure 10.—Custom enstatite tip after breaking during scratch testing. The original tip shape is shown as black silhouette in the background. Magnification is 50x.

5.0 Conclusions

A new methodology utilizing advanced profilometry capabilities is proposed to provide a more thorough and systematic characterization of surface abrasion using the suite of metrics described in this work. Defining the ZOI serves to remove prior ambiguity of measurement boundary conditions, and allows a means of normalizing the sample material removal and displacement that can occur during scratch testing. It was demonstrated that inclusion of these additional quantifiable variables could be used to discern differences in scratch test results that were previously undetectable based on width measurement alone. Based on this study, a new standard is put forward for general scratch test analysis guidelines. Finally, it is shown how this methodology can be extended toward application-driven needs that require customized scratch tips. Overall, this work lays an analytical foundation for characterizing more complex material interactions from two-body into three-body abrasion tests that will ultimately be needed for system level design applications.

References

1. Tylczak, J.H. (1992): “Abrasive Wear,” in ASM Handbook, 18, Friction, Lubrication, and Wear Technology. Edited by S.D. Henry, ASM International, Cleveland, OH. pp. 187–189.
2. Rickman, D., and Street, K.W. (2008): “Expected Mechanical Characteristics of Lunar Dust: A Geological View,” Proceedings of the Space Technology and Applications International Forum, Albuquerque, NM.
3. Cole, D.M., Taylor, L.A., Liu, Y., and Hopkins, M.A. (2010): “Grain-scale mechanical properties of lunar plagioclase and its simulant: Initial experimental findings and modeling implications,” Earth & Space 2010: Engineering, Science, Construction, and Operations in Challenging Environments. ASCE. pp. 74–83.
4. Sunshine, J.M., Besse, S., Petro, N.E., Pieters, C.M., Head, J.W., Taylor, L.A., Klima, R.L., Isaacson, P.J., Boardman, J.W., Clark, R.C. and the M3 Team (2010): “Hidden in Plain Sight: Spinel-Rich Deposits on the Nearside of the Moon as Revealed by Moon Mineralogy Mapper (M3),” (abstract). 41st Lunar and Planetary Science Conference. Abstract No. 1508. The Woodlands, Texas.
5. Kobrick, R.L., Klaus, D.M., and Street, Jr., K.W. (2010, Submitted): “Standardization of a Volumetric Displacement Measurement for Two-Body Abrasion Scratch Test Data Analysis,” J. WEAR. Manuscript number: IH-6025. Elsevier.
6. ASTM (2003): “Standard Test Method for Scratch Hardness of Materials Using a Diamond Stylus,” G 171-03, Annual Book of ASTM Standards.
7. WYKO (1999): “WYKO Vision32 Online Help,” WYKO Vision32 software for NT-2000, Version 2.210, Veeco Instruments, Inc., Metrology Group. Release Date 1/8/1999. Available via software package.
8. Gaier, J.R. (2007): “The Effects of Lunar Dust on EVA Systems During the Apollo Missions,” NASA GRC. NASA/TM—2005-213610/REV1.

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)* 01-02-2011	**2. REPORT TYPE** Technical Memorandum	**3. DATES COVERED** *(From - To)*

4. TITLE AND SUBTITLE Validation of Proposed Metrics for Two-Body Abrasion Scratch Test Analysis Standards	**5a. CONTRACT NUMBER**
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) Kobrick, Ryan, L.; Klaus, David, M.; Street, Kenneth, W., Jr.	**5d. PROJECT NUMBER**
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER WBS 936374.03.01.03
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) National Aeronautics and Space Administration John H. Glenn Research Center at Lewis Field Cleveland, Ohio 44135-3191	**8. PERFORMING ORGANIZATION REPORT NUMBER** E-17544
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) National Aeronautics and Space Administration Washington, DC 20546-0001	**10. SPONSORING/MONITOR'S ACRONYM(S)** NASA
	11. SPONSORING/MONITORING REPORT NUMBER NASA/TM-2011-216940

12. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified-Unlimited
Subject Categories: 48 and 88
Available electronically at http://www.sti.nasa.gov
This publication is available from the NASA Center for AeroSpace Information, 443-757-5802

13. SUPPLEMENTARY NOTES
Submitted to Wear Journal (ELSEVIER).

14. ABSTRACT

The objective of this work was to evaluate a set of standardized metrics proposed for characterizing a surface that has been scratched from a two-body abrasion test. This is achieved by defining a new abrasion region termed “Zone of Interaction” (ZOI). The ZOI describes the full surface profile of all peaks and valleys, rather than just measuring a scratch width as currently defined by the ASTM G 171 Standard. The ZOI has been found to be at least twice the size of a standard width measurement, in some cases considerably greater, indicating that at least half of the disturbed surface area would be neglected without this insight. The ZOI is used to calculate a more robust data set of volume measurements that can be used to computationally reconstruct a resultant profile for detailed analysis. Documenting additional changes to various surface roughness parameters also allows key material attributes of importance to ultimate design applications to be quantified, such as depth of penetration and final abraded surface roughness. Data are presented to show that different combinations of scratch tips and abraded materials can actually yield the same scratch width, but result in different volume displacement or removal measurements and therefore, the ZOI method is more discriminating than the ASTM method scratch width. Furthermore, by investigating the use of custom scratch tips for our specific needs, the usefulness of having an abrasion metric that can measure the displaced volume in this standardized manner, and not just by scratch width alone, is reinforced. This benefit is made apparent when a tip creates an intricate contour having multiple peaks and valleys within a single scratch. This work lays the foundation for updating scratch measurement standards to improve modeling and characterization of three-body abrasion test results.

15. SUBJECT TERMS
Two-body abrasion; Scratch testing; Lunar dust; Surface topography; Profilometry; Surface analysis

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON** STI Help Desk (email:help@sti.nasa.gov)
a. REPORT U	**b. ABSTRACT** U	**c. THIS PAGE** U	UU	17	**19b. TELEPHONE NUMBER** *(include area code)* 443-757-5802