Designation: G163 – 10

Standard Guide for
Digital Data Acquisition in Wear and Friction Measurements[1]

This standard is issued under the fixed designation G163; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers the providing of general guidance in applying hardware and software to digitally acquire wear and friction data in laboratory test systems. It points out important considerations in such data acquisition. It does not make specific recommendations or discuss specific details regarding commercial hardware or software.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

G40 Terminology Relating to Wear and Erosion

G77 Test Method for Ranking Resistance of Materials to Sliding Wear Using Block-on-Ring Wear Test

G83 Test Method for Wear Testing with a Crossed-Cylinder Apparatus (Withdrawn 2005)[3]

G99 Test Method for Wear Testing with a Pin-on-Disk Apparatus

G115 Guide for Measuring and Reporting Friction Coefficients

G118 Guide for Recommended Format of Wear Test Data Suitable for Databases

3. Terminology

3.1 *Definitions:*

3.1.1 *coefficient of friction, n*—the dimensionless ratio of the friction force between two bodies to the normal force pressing the bodies together.

3.1.2 *wear, n*—alteration of a solid surface by progressive loss or progressive displacement of material due to relative motion between that surface and a contacting substance or substances. **G40**

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *hardware, n*—mechanical and electronic components in instrumentation used to acquire data.

3.2.2 *software, n*—computer code that can be executed to control hardware systems and store data.

4. Summary of Guide

4.1 Several important issues relating to digital data acquisition in wear and friction measurements are identified and explained. Hardware and software choices are described in general terms, along with some important considerations in data storage.

5. Significance and Use

5.1 This guide illustrates the steps and considerations involved with digital data acquisition. While analog recording of wear and friction data has been in the past, digital data acquisition and storage is used extensively. It is important that DAQ users understand how data is collected and stored and how data manipulation may affect raw data integrity.

5.2 Multi-station wear and friction testing is increasing in use, and because of the increased volume of data in such approaches, the use of digital data acquisition facilitates such testing.

5.3 The same hardware and software used for the initial analog data conversion to digital form can often also be used for initial data processing, for example, multiple-point averaging. This can conveniently lead to computer-based storage of processed data in digital form. However, where possible, the storage of unfiltered (software filters) and unmanipulated data will allow reevaluation of original data should calibration coefficients need to be adjusted.

5.4 Databases are frequently constructed in computerized format (see Guide G118) in order to hold large amounts of wear and friction data from laboratory test programs.

---

[1] This guide is under the jurisdiction of ASTM Committee G02 on Wear and Erosion and is the direct responsibility of Subcommittee G02.20 on Data Acquisition in Tribosystems.

Current edition approved April 1, 2010. Published April 2010. Originally approved in 1999. Last previous edition approved in 2004 as G163–99(2004). DOI: 10.1520/G0163-10.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

6. Hardware and Software

6.1 *Hardware*—Necessary electronic components associated with the wear test system include sensors (for example, force transducers, strain gages, linear variable differential transformers), a data acquisition system (for example, analog signal conditioners, filters, analog-to-digital convertors, other electronic circuits), a controlling computer, and a digital data storage device. These items can be bought commercially, or constructed specifically for the task (**1-3**).[4]

6.2 *Data Acquisition System*—Typically consists of an electronic amplifier/filter system that receives and conditions sensor data, and whose output is fed to a scanning or multiplexing circuit designed to handle multiple inputs. Systems are commercially available to read voltage, current, or resistance. The analog signals are then digitized in a data convertor and sent to temporary or permanent storage in digital form, possibly after pre-processing the digital data. The system can be either of a stand-alone design or in the form of printed circuit cards that reside in the controlling computer (**2**, **3**).

6.3 *Analog-to-Digital Convertor Resolution and Accuracy*—Present technology typically offers either 12 bit or 16 bit data conversion, with ±1 least significant digit as the usual resolution, and over a voltage range of typically ±5 V or ±10 V. It is important to match the selected resolution to each application. For example 12 bit resolution involves 1 part in 4096 resolution. For a full scale of ±5 V, the voltage resolution would be 2.4 mV. This may be sufficient for an amplified signal of 1 or 2 V level, but might be insufficient for a signal level as low as 0.1 V. Such resolution would be clearly insufficient for raw thermocouple signals of a few mV. Accuracy of data conversion is usually maintained by self-calibrating electronic features that are built-in to the hardware. However, it is recommended that manual voltage calibration also be done periodically to ensure against any electronic component drift or failure.

6.4 *Software*—Necessary software includes code that operates the data acquisition system, as well as code that operates the computer and necessary peripherals.

6.4.1 *Source of Software*—Usually commercial software is obtained to operate the controlling computer. Vendors of digital data acquisition hardware usually offer modular software codes that can be assembled together to carry out many measurement operations. The user can usually configure that software to suit his needs, and may be able to add self-written code to further adapt the overall software, if necessary. Care must be taken to ensure the data collection speed is correct when using any DAQ system.

7. Procedure

7.1 *Sampling Rate and Number of Channels*—Information theory recommends sampling a waveform at a rate of 10 times the highest frequency present, in order to accurately reconstruct the waveform. In practical terms, the factor may be reduced to three times that of the highest significant frequency in the data. For multi-channel systems, the overall sampling rate must be increased in proportion to the number of channels scanned. As an example, for a 0 to 10 Hz bandwidth signal and a data convertor set to scan five channels, the recommended overall sampling rate is 500 Hz (that is, each recommended channel sampling rate is $10 \times 10 = 100$ Hz). Many wear test systems involve a mechanical rotation frequency that is present to some degree in the sensor output signals. For example, in a pin-on-disk system, a disk rotating at 60 rpm could inject a 1 Hz component into a friction force transducer output, usually due to lack of flatness or misalignment of the disk. As a result, ideally a one channel system should scan at least at 10 Hz (or a five channel system at 50 Hz) to accurately record that effect.

7.2 *Electronic Noise*—Spurious signals may appear along with sensor outputs as a result of electronic interference. The interference frequencies may be related to ac voltage supply or characteristic signals of other equipment. Such noise signals may seriously complicate proper data acquisition. An oscilloscope may be used to help identify interfering signals. It is recommended that proper shielding of signal leads, minimizing of lead length, and proper grounding, all be practiced to a high level to avoid problems with data validity later. Good analog signals must be available through proper conditioning before digital conversion is attempted. Low pass filtering of the analog signal may be required to improve its quality.

7.3 *Calibration*—Overall system calibration includes voltage calibration at sensor input levels, and sensor calibration using directly applied force, temperature, and so forth. Ideally, some partial calibration is applied on every separate occasion of use of the system, and for unusually long tests, even at some intervals during the test. Complete system calibration should be done at some suitable interval such as monthly or quarterly. Calibration should involve input levels close to that normally experienced, and also somewhat larger levels. Calibration should be done under conditions close to those of usual system operation. Any deviations from linearity that exist for any part of the measuring system should be determined, and corrections to the data applied as needed.

7.4 *Data Storage*—Usually, the data stream is accumulated in the controlling computer memory, and periodically transferred to an associated hard disk storage system in the form of a text file. In some cases, the data are automatically placed into a spreadsheet file (a row versus column organization) by the operating software. In other cases, the data file can at a later time be loaded into a database or spreadsheet. The organization of the data file is important to the extent that necessary descriptors of the test are saved. Guide G118 should be consulted for assistance in deciding on the database format, along with the Report section in any standard that applies to the test involved.

7.5 *Data Reduction Online*—An important advantage of digital data acquisition is that it gives the capability to carry out online data reduction to reduce the volume of data to be stored. This can be done using simple smoothing algorithms which perform a running average or other similar function to yield average values of the different parameters which are then stored in a datafile for the test. More sophisticated algorithms

[4] The boldface numbers in parentheses refer to a list of references at the end of this standard.

can also be used which have the ability to adjust the data reduction and storage rate to reflect the speed of changes in the data. This type of analysis, often termed adaptive storage, is useful for situations where the data values are steady for long periods with intervals where the data change quickly. In all cases where online data reduction is used, it is important to ensure that the strategy employed will retain all essential features of the data. The storage of original data will allow reevaluation should calibration coefficients need to be adjusted or smoothing routines prove to be excessive.

8. Report

8.1 *Wear Testing*—Examples of wear testing methods that have been followed using digital data acquisition systems include block-on-ring (Practice G77), crossed cylinder (Test Method G83), and pin-on-disk (Test Method G99) (**4, 5**). Other ASTM wear tests may also lend themselves to that approach. In these three cases cited, there was no conflict with any requirements in those standards. Sensors may be added to those test rigs to measure, for example, wear displacement, normal load, temperature, background vibration amplitudes, and frequencies, and so forth, without concern over conflicting with the standard requirements. Actually, such additional measures have merit as they further describe the wear conditions being applied in the test. The effects of adding a sensor on a test apparatus (particularly system stiffness) should be considered in sensor type and location. Furthermore, the effect of electrical excitation of surfaces used in some electrical measurements may affect the tribological conditions at the surface.

8.2 *Friction Testing*—Several friction testing rigs mentioned in Guide G115 have been instrumented for digital data acquisition. Most of the considerations mentioned in the previous section also apply in friction measurements. See also comments in 8.1.

9. Keywords

9.1 data acquisition; database; digital data; friction; hardware; software; tribology; wear

REFERENCES

(**1**) Finkel, J., Computer-Aided Experimentation: Interfacing to Minicomputers, Wiley-Interscience, New York, 1975.

(**2**) Daugherty, K. M., Analog-to-Digital Conversion: A Practical Approach, McGraw-Hill, NY, 1995.

(**3**) Hoeschele, Jr., D. F., Analog-to-Digital and Digital-to-Analog Conversion Techniques, Wiley, New York, 1994.

(**4**) Whitenton, E. P., and Ruff, A. W., "A Computer-controlled Test System for Operating Different Wear Test Machines," *NISTIR* 89-4107, 1989.

(**5**) Chen, Z. and Liu, P., Signal Processing Techniques for Friction Measurement, 1997.