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Standard Practice for Calibration of Linear Displacement Sensor Systems Used to Measure Micromotion[1]

This standard is issued under the fixed designation F2537; 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 practice covers the procedures for calibration of linear displacement sensors and their corresponding power supply, signal conditioner, and data acquisition systems (linear displacement sensor systems) for use in measuring micromotion. It covers any sensor used to measure displacement that gives an electrical voltage output that is linearly proportional to displacement. This includes, but is not limited to, linear variable differential transformers (LVDTs) and differential variable reluctance transducers (DVRTs).

1.2 This calibration procedure is used to determine the relationship between output of the linear displacement sensor system and displacement. This relationship is used to convert readings from the linear displacement sensor system into engineering units.

1.3 This calibration procedure is also used to determine the error of the linear displacement sensor system over the range of its use.

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

1.5 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Terminology

2.1 *Definitions:*

2.1.1 *calibrated range, n*—distance over which the linear displacement sensor system is calibrated.

2.1.2 *calibration certificate, n*—certification that the sensor meets indicated specifications for its particular grade or model and whose accuracy is traceable to the National Institute of Standards and Technology or another international standard.

2.1.3 *core, n*—central rod that moves in and out of the sensor.

[1] This practice is under the jurisdiction of ASTM Committee F04 on Medical and Surgical Materials and Devices and is the direct responsibility of Subcommittee F04.15 on Material Test Methods.

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2.1.3.1 *Discussion—*
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2.1.4 *data acquisition system, n*—system generally consisting of a terminal block, data acquisition card, and computer that acquires electrical signals and allows them to be captured by a computer.

2.1.5 *differential variable reluctance transducer (DVRT), n*—a linear displacement sensor made of a sensor housing and a core. The sensor housing contains a primary coil and a secondary coil. Core position is detected by measuring the coils' differential reluctance.

2.1.6 *linear displacement sensor, n*—an electrical sensor that converts linear displacement to electrical output.

2.1.7 *linear displacement sensor system, n*—a system consisting of a linear displacement sensor, power supply, signal conditioner, and data acquisition system.

2.1.8 *linear variable differential transformer (LVDT), n*—a linear displacement sensor made of a sensor housing and a core. The sensor housing contains a primary coil and two secondary coils. When an ~~ac~~ alternating current (AC) excitation signal is applied to the primary coil, voltages are induced in the secondary coils. The magnetic core provides the magnetic flux path linking the primary and secondary coils. Since the two voltages are of opposite polarity, the secondary coils are connected in series opposing in the center, or null position. When the core is displaced from the null position, an electromagnetic imbalance occurs. This imbalance generates a differential ~~ac~~AC output voltage across the secondary coils, which is linearly proportional to the direction and magnitude of the displacement. When the core is moved from the null position, the induced voltage in the secondary coil, toward which the core is moved, increases while the induced voltage in the opposite secondary coil decreases.

2.1.9 *null position, n*—the core position within the sensor housing where the sensor voltage output is zero (some sensors do not have a null position).

2.1.10 *offset correction, n*—removal of any offset in a sensor's output so that at zero displacement, zero voltage is recorded.

2.1.11 *percent error, n*—the difference between a measurement of a reference standard and the actual length of the reference standard divided by the actual length of the reference standard and the result converted to a percent.

2.1.12 *power supply, n*—a regulated voltage source with output equal to that required by the sensor for proper operation.

2.1.13 *sensor housing, n*—central hole in a linear displacement sensor that senses movement of the core within it.

2.1.14 *signal conditioner, n*—electronic equipment that acts to convert the raw electrical output from the linear displacement sensor into a more useful signal by amplification and filtering.

3. Summary of Practice

3.1 A linear displacement sensor is mounted in a calibration fixture ~~such that~~ so it can be subjected to a precise, known displacement.

3.2 Displacement is applied in steps over the full range of the linear displacement sensor and electrical readings (for example, voltages) are collected using the linear displacement sensor system.

3.3 Each voltage reading is taken as the average of 100 readings over 0.1 s, decreasing the error of the reading. The error in the readings is recorded as the standard deviation in the readings. This error should be constant and independent of displacement. It should be noted that the error in the readings is a summation of errors in each of the linear displacement sensor system components.

3.4 The calibration factor (S) is calculated as the slope of the voltage versus displacement curve using linear regression.

3.5 Linearity of the sensor is assessed.

3.6 The percent error is determined for each calibration point collected. This percent error is evaluated together with the tolerance of the micrometer head calibration.

4. Significance and Use

4.1 Linear displacement sensor systems play an important role in orthopedic applications to measure micromotion during simulated use of joint prostheses.

4.2 Linear displacement sensor systems must be calibrated for use in the laboratory to ensure reliable conversions of the system's electrical output to engineering units.

4.3 Linear displacement sensor systems should be calibrated before initial use, at least annually thereafter, after any change in the electronic configuration that employs the sensor, after any significant change in test conditions using the sensor that differ from conditions during the last calibration, and after any physical action on the sensor that might affect its response.

4.4 Verification of sensor performance in accordance with calibration should be performed on a per use basis both before and after testing. Such verification can be done with a less accurate standard than that used for calibration, and may be done with only a few points.

4.5 Linear displacement sensor systems generally have a working range within which voltage output is linearly proportional to displacement of the sensor. This procedure is applicable to the linear range of the sensor. Recommended practice is to use the linear displacement sensor system only within its linear working range.

5. Apparatus and Equipment

5.1 *Linear Displacement Sensor.*

5.2 *Power Supply,* with output equal to that required by the sensor.

5.3 *Signal Conditioner, Data Acquisition System, and Related Cables and Fittings.*

5.4 *Test Method—Micrometer Fixture Calibration:*

5.4.1 *Calibration Fixture,* a fixture that provides a means for fixing both a micrometer head and the linear displacement sensor along a parallel displacement axis, and is capable of applying displacement to the linear displacement sensor throughout its linear range. The alignment tolerance of the calibration fixture must be measured.

5.4.2 *Micrometer Head,* a precision instrument with known error (that is, tolerance). The spindle of the micrometer must be non-rotating and spring-loaded. The micrometer head shall be calibrated annually by the manufacturer or other qualified personnel.

6. Hazards

6.1 *Safety Hazards:*

6.1.1 This practice involves electrical equipment. Verify that all electrical wiring is connected properly and that the power supply and signal conditioner are grounded properly to prevent electrical shock to the operator. Take necessary precautions to avoid exposure to power signals.

6.2 *Safety Precautions:*

6.2.1 Examine the sensor housing for burrs or sharp edges, or both. Remove any protrusions that might cause harm.