Designation: F3109 – 22

Standard Practice for Verification of Multi-Axis Force Measuring Platforms[1]

This standard is issued under the fixed designation F3109; 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 standard recommends practices for performance verification of multi-axis force platforms commonly used for measuring ground reaction forces during gait, balance, and other activities.

1.1.1 This standard provides a method to quantify the relationship between applied input force and force platform output signals across the manufacturer's defined spatial working surface and specified force operating range.

1.1.2 This standard provides definitions of the critical parameters necessary to quantify the behavior of multi-axis force measuring platforms and the methods to measure the parameters.

1.1.3 This standard presents methods for the quantification of spatially distributed errors and absolute measuring performance of the force platform at discrete spatial intervals and discrete force levels on the working surface of the platform.

1.1.4 This standard further defines certain important derived parameters, notably COP (center of pressure) and methods to quantify and report the measuring performance of such derived parameters at spatial intervals and force levels across the working range of the force platform.

1.1.5 This standard defines the requirements for a report suitable to characterize the force platform's performance and provide traceable documentation to be distributed by the manufacturer or calibration facility to the users of such platforms.

1.1.6 Dynamic characteristics and applications where the force platform is incorporated in other equipment, such as instrumented treadmills and stairs, are beyond the scope of this standard.

1.1.7 This standard is written for purposes of multi-axis force platform verification. However, the methods and procedures are applicable to calibration of force platforms by manufacturers.

1.2 The values stated in SI units are to be regarded as the standard. Other metric and inch-pound values are regarded as equivalent when required.

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

1.4 *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. Referenced Documents

2.1 *ASTM Standards:*[2]

E4 Practices for Force Calibration and Verification of Testing Machines

E74 Practices for Calibration and Verification for Force-Measuring Instruments

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *center of pressure (COP), n*—the spatial point on the surface of a force platform at which a single equivalent force has the same static effect as the sum of the distributed forces and the distributed moments acting on the system.

3.1.2 *COP error, n*—difference between the COP x-y position reported by the force platform (or calculated from the force platform outputs) and the actual x-y location of the applied Fz verification force.

3.1.3 *crosstalk or crosstalk error, n*—response of an output channel corresponding to an unloaded axis when a force or a moment is applied to a different axis.

3.1.4 *force platform origin, n*—the position on the force platform, specified by the manufacturer, where x, y, and z = 0. The origin serves as a reference position for the COP x and

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[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.

***A Summary of Changes section appears at the end of this standard**

COP y locations, locations for uniaxial forces applied during verification, and for calculating output moments due to input forces. The origin may be at a different x-y-z position from the force platform's geometric center. The force platform origin is sometimes called the electro-mechanical origin.

3.1.5 *Fx and Fy, n*—forces orthogonal to Fz, assigned per Fig. 1 which follows the right-hand coordinate system ("right-hand rule") convention for directionality.

3.1.6 *Fz, n*—force that is orthogonal to the working surface of the platform. Fz and z distances are positive going downward when the force platform is mounted on the floor.

3.1.7 *moment, n*—a vector equal to the cross product of a position vector and a force vector. Given a position vector d = {x, y, z} that indicates a point, relative to a given origin, which is on the line of action of a force F = {Fx, Fy, Fz} then the components of the moment vector M = {Mx, My, Mz} relative to the origin are:

$$Mx = y \cdot Fz - z \cdot Fy$$
$$My = z \cdot Fx - x \cdot Fz$$
$$Mz = x \cdot Fy - y \cdot Fx$$

If the point indicated by d lies on the surface of the force platform, then that point is also the COP of F.

3.1.8 *Mx, My, and Mz, n*—moments around the x, y, and z axes, respectively, following the right-hand coordinate system convention for directionality.

3.1.9 *multi-axis force plate, n*—synonym for multi-axis force platform.

3.1.10 *multi-axis force platform, n*—a transducer with a flat measuring surface capable of measuring three orthogonal force components, three orthogonal moment components, and directly or indirectly measuring the center of pressure x-y position.

3.1.11 *serialized calibration values, n*—calibration values that apply to a specific force platform with a specific serial number. The calibration values may be used in the force platform, in an amplifier, or in a computer that makes up a calibrated force-measuring platform system.

3.1.12 *traceable force standard, n*—a force transducer or dead weight that is traceable to national standards and is more accurate than the instrumentation that is being verified. In this method, if dead weights are used then corrections for gravity shall be applied per Practice E4 and their center of mass shall be spatially balanced around the axis of loading such that forces applied to the force platform are applied at a known location.

3.1.13 *uniaxial force, n*—force that is only in the direction of the intended axis without imparting forces in the two orthogonal axes. For example, applying Fz uniaxially shall not cause Fx or Fy forces greater than 10 % of the Fz to Fx or Fz to Fy crosstalk specified by the force platform's manufacturer.

3.1.14 *working surface, n*—the flat area of the platform where ground reaction forces are measured while patients or subjects perform activities such as walking, standing, running, and other activities. In most applications the working surface is oriented horizontally and is the top surface of the force platform.

3.1.15 *x-y-z position, n*—the position where the force verification vector is applied with respect to the force platform's origin.

4. Summary of Practice

4.1 This standard practice has three sections:

4.1.1 Uniaxial test forces are applied to the force platform using traceable force standards. The forces are applied for at

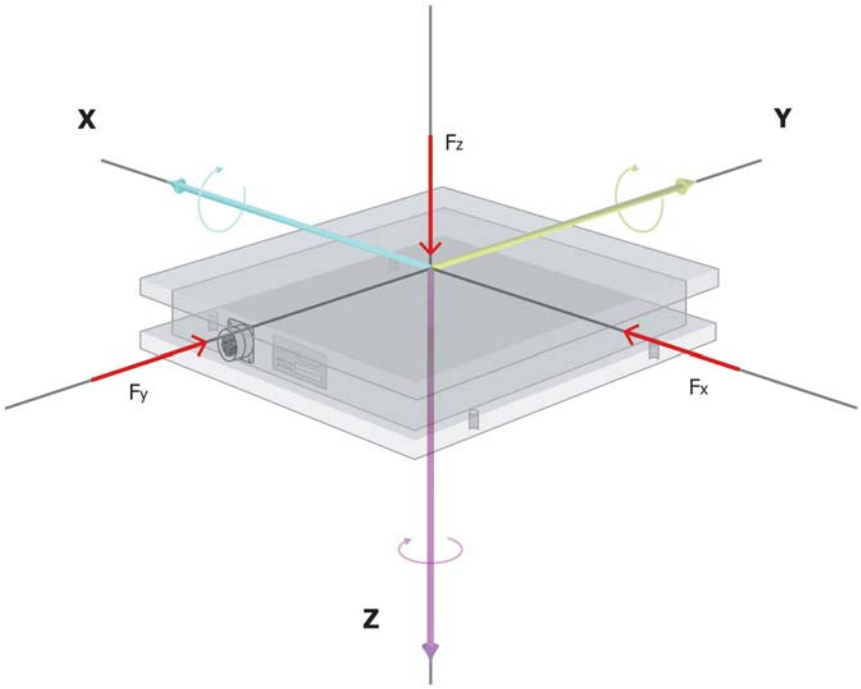

FIG. 1 Force Platform Orthogonal Coordinate Conventions

least five force values over a range of positions spanning the manufacturer's specified working surface dimensions. The force platform's outputs are recorded at each force and position. To ensure adequate quality of measurement at all locations of force application, the spatial errors should be sampled by test forces at appropriately small spatial intervals. In this standard, a grid pattern to ensure proper spatial characterization of errors is presented (see Fig. 2).

4.1.2 The recorded force platform outputs are analyzed at all forces and positions to compare the force platform's Fx, Fy, Fz, Mx, My, Mz, COP x, and COP y measuring errors and crosstalk performance with the manufacturer's specifications. These comparisons determine whether the force platform is successfully verified.

4.1.3 A report which includes graphical presentation of the results shall be prepared.

5. Significance and Use

5.1 Multi-axis force measuring platforms are used to measure the ground reaction forces produced at the interface between a subject's foot or shoe and the supporting ground surface. These platforms are used in various settings ranging from research laboratories to healthcare facilities. The use of force platforms has become particularly important in gait analysis where clinical evaluations have become a billable clinical service.

5.2 Of particular importance is the application of force platforms in the treatment of cerebral palsy (CP) (**1**, **2**).[3] An estimated 8000 to 10 000 infants born each year will develop CP (**3**) while today's affected population is over 764 000 patients (**4**). Quantitative gait analysis, using force platforms and motion capture systems, provides a valuable tool in evaluating the pathomechanics of children with CP. This type of mechanical evaluation provides a quantitative basis for treating neuromuscular conditions. In other words, surgical decisions are in part guided by information gained from the use of force platform measurements (**5**, **6**).

5.3 Another application is treatment of spina bifida. According to the Gait and Clinical Movement Analysis Society (GCMAS) (**7**), an instrumented gait analysis is the standard of expert care for children with gait abnormalities secondary to spina bifida. The main objective of diagnostic gait analysis is to define the pathological consequences of neural tube defects as they relate to gait. The use of instrumented gait analysis allows physicians to determine which surgical or non-surgical interventions would provide the best outcome.

5.4 More recently, force platforms have been used for pre- and post-surgical evaluation of TKA (total knee arthroplasty) and THA (total hip arthroplasty) patients. Such data provides an objective measure of the mechanical outcome of the surgical procedure.

5.5 In addition to the clinical applications there are numerous medical and human performance research activities which rely on accurate measurement of ground reaction forces by using multi-axis force platform measurement instruments.

5.6 As a standards organization, ASTM has historically provided excellent standards for the calibration of force transducers and force-measuring instrumentation. Force platforms,

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

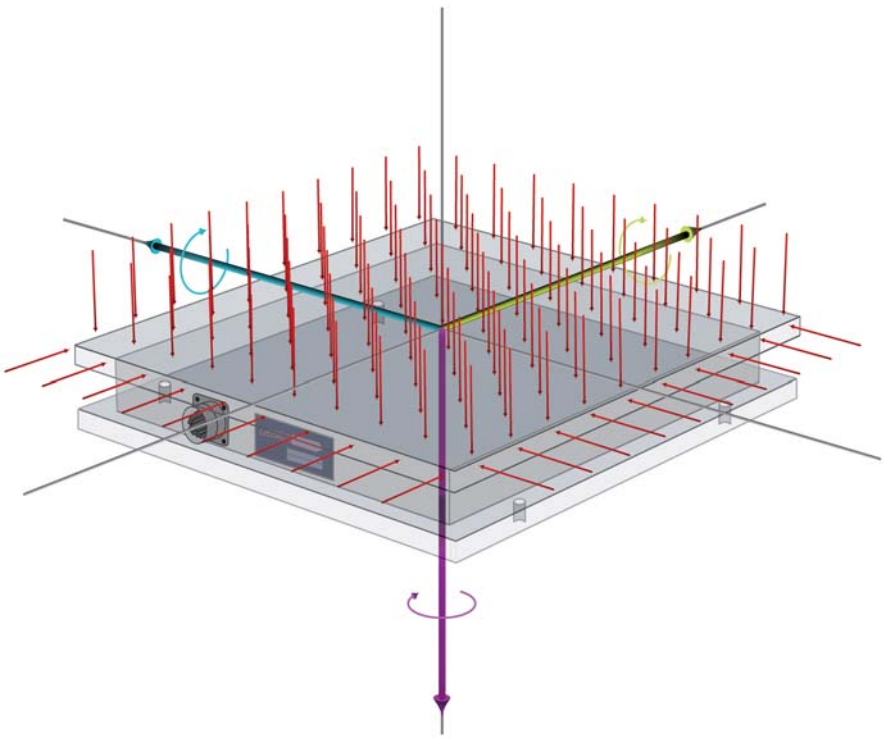

FIG. 2 Illustration of Spatial Grid Pattern Used to Apply Forces for Force Platform Verification