Rotary Stage Terminology

There are many factors that affect the ability of a rotary stage to perform accurately. Axis of rotation error motions, hysteresis, backlash, encoder errors, mounting surface quality and applied loads all contribute to the quality and performance of a rotary stage or spindle. The following discussion defines and explains these errors in greater detail, as well as some other pertinent nomenclature relating to rotary stages and spindles.

Axis of rotation error motion – An error motion of a rotary stage's axis of rotation is defined as a change in position, relative to the reference coordinate axes, of the surface of a perfect workpiece, as a function of rotation angle, with the workpiece centerline coincident with the axis of rotation. From this point forward, axis of rotation error motion is designated as "error motion".

Runout (TIR) – Runout is defined as the total displacement measured by an indicator sensing against a moving surface or moved with respect to a fixed surface. Runout is not an error of a rotary stage's axis of rotation. The runout of a rotary stage includes errors in setup (e.g., centering errors) and roundness errors of a tabletop, workpiece or measurement artifact. If you can physically put an indicator on a surface, you are measuring the runout of that surface and not an error motion.

Note – To measure an error motion of a rotary stage, the runout of a surface (typically a measurement artifact) needs to be measured. Setup errors and workpiece/artifact errors are removed during post-processing and the result is the error motion(s) of the rotary stage under test. Aerotech specifies rotary stage axis of rotation performance using three main error motion types – tilt, axial and radial error motion. For certain rotary stages or spindles, these error motions are broken down further into subsets such as synchronous and asynchronous error motions. Unless otherwise specified, the error motion values reported in the specification tables are the total error motion of the rotary device.

Synchronous error motion – Synchronous error motion is defined as the component of the total error motion that occurs at integer multiples of the rotation frequency. The term "average error motion" is equivalent, but no longer a preferred term. For example, if N revolutions of data are collected, then the synchronous error motion is calculated first by averaging N readings at each discrete angular position. Then, the peak-to-valley number of all average readings at every angular position is reported as the synchronous error motion (refer to Figure 1).

Asynchronous error motion – Asynchronous error motion is defined as the component of the total error motion that occurs at noninteger multiples of the rotation frequency. Asynchronous error motion comprises those components of error motion that are: (i) not periodic, (ii) periodic but occur at frequencies other than the rotation frequency and its integer multiples, and (iii) periodic at frequencies that are subharmonics of the rotation frequency. Asynchronous error is what remains after the synchronous portion is removed from the total error motion value. The largest peak-to-valley number at each measured angular position is reported as the asynchronous error of the rotary stage under test (refer to Figure 1). In certain industry segments, the term nonrepeatable runout (or NRRO) is used in place of asynchronous error motion.

Total error motion – Total error motion is defined as the complete error motion as recorded by the displacement indicator. Referring to Figure 1, it would be the maximum radius less the minimum radius including both the synchronous and asynchronous terms.

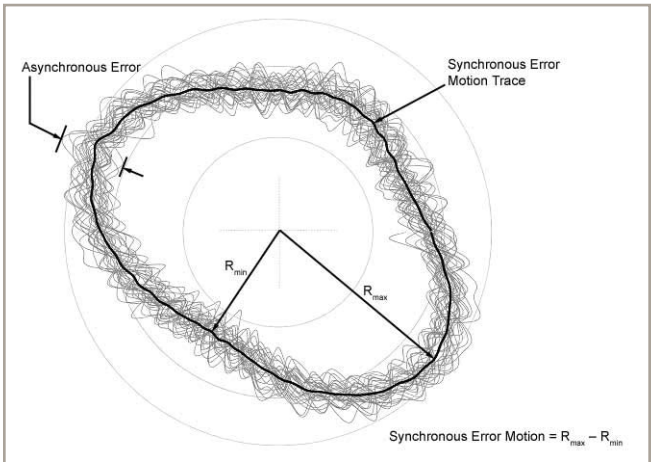

Figure 1: Graphical representation of synchronous and asynchronous error motion.

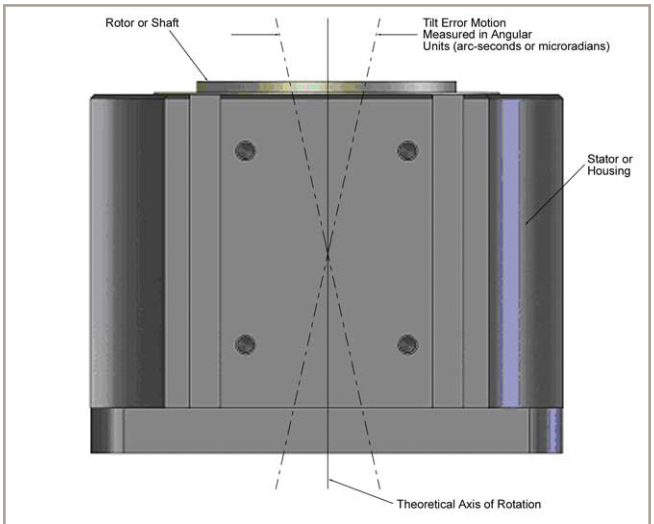

Figure 2: Tilt error motion illustration.

Rotary Stage Terminology

Tilt error motion — Tilt error motion is defined as the error motion in an angular direction relative to the rotary stage axis of rotation (see Figure 2). In previous specification tables published by Aerotech, the term "wobble" was used and is synonymous; however, "wobble" is no longer preferred. Tilt error motion is reported as an angular value (arc-seconds, microradians, etc.).

Axial error motion – Axial error motion is defined as error motion that occurs coaxial with the rotary stage axis of rotation (see Figure 3). Axial error motion is not to be confused with tabletop or shaft end runout.

Radial error motion – Radial error motion is defined as error motion that occurs perpendicular to the rotary stage axis of rotation at a specified axial location (see Figure 4). Unless otherwise specified, Aerotech measures radial error at an axial location of 50 mm above the tabletop or shaft end.

Hysteresis error — A deviation between the actual and commanded position at the point of interest caused by elastic forces in the motion system. Hysteresis also affects bi-directional repeatability. For Aerotech rotary stages, accuracy and repeatability errors caused by hysteresis are accounted for in the stage specification tables. Elastic forces in the machine base, load and load coupling hardware must also be examined and minimized for optimal performance.

Backlash error — An error in positioning caused by the reversal of travel direction. Backlash is the portion of commanded motion that produces no change in position upon reversal of travel direction. Backlash is caused by clearance between elements in the drive train. As the clearance increases, the amount of input required to produce motion is greater. This increase in clearance results in increased backlash error. Backlash also affects repeatability. Unidirectional repeatability refers to the repeatability when approached from the same direction. It does not take into account the effects of backlash. Bidirectional repeatability specifies the repeatability when approached from any direction and includes the effects of backlash. Aerotech controllers have the capability to correct for backlash, if required. All of Aerotech's direct-drive tables exhibit zero backlash error.

Encoder error — Imperfections in the operation of the encoder such as non-uniform division of the grating scale, encoder grating runout, imperfections in the photodetector signal, interpolator errors, hysteresis, friction and noise can affect the positioning capabilities of the rotary stage. For a rotary stage, the accuracy and repeatability information in the specification tables takes all of these errors into account.

Mounting surface quality – For the rotary stage or spindle to perform to the specifications listed in the catalog, the mounting surface(s) need to be flat. Consult an Aerotech applications engineer for the appropriate tolerance(s) required for each specific rotary stage or spindle.

Applied loads – When a load is placed on a rotary stage or spindle, deflection occurs due to the finite compliance of the structure and bearings. The amount of deflection is dependent upon the applied load and the structural stiffness of the stage and mounting surfaces. Depending on the application, this applied load may cause a deflection that is detrimental to the process. Consult an Aerotech applications engineer if the applied load is large or if there is concern about load-induced errors on the rotary stage or spindle.

Reference: ANSI/ASME B89.3.4M, Axes of Rotation – Methods for Specifying and Testing

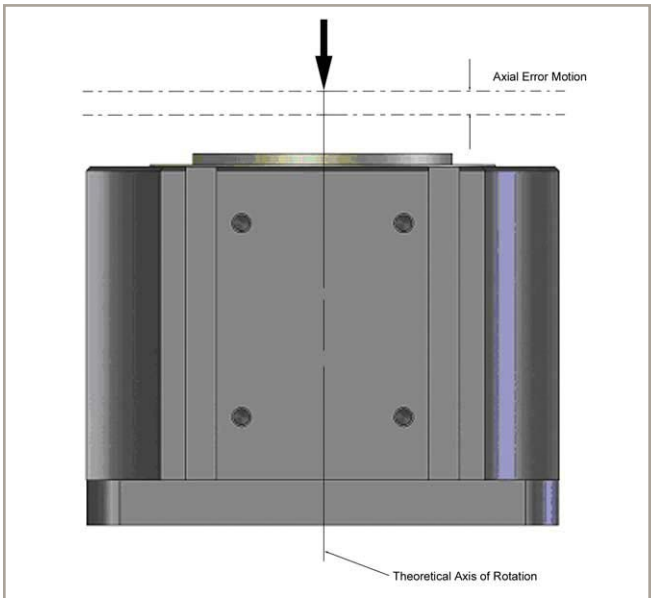

Figure 3: Axial error motion illustration.

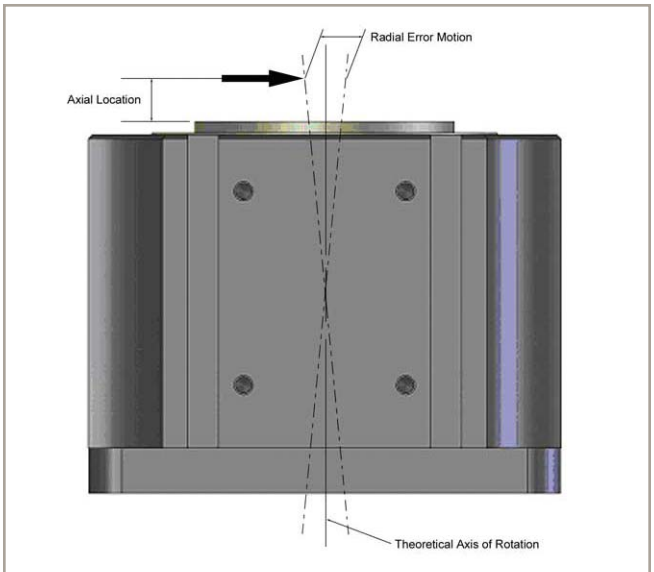

Figure 4: Radial error motion illustration.