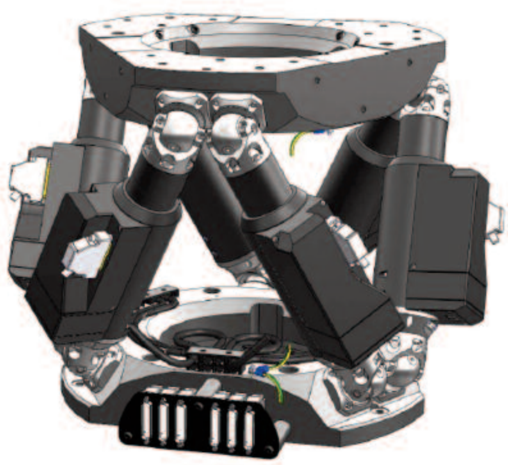
Motion in 3-D: Newport Hexapod Coordinate Systems



Controlling Motion in 3-D space requires a user to have a clear understanding of the relationship between end effector positions and positions of devices under test. Regardless of whether it is an industrial positioning platform used in machinery, using a cutting tool and a work piece, or an electro-optical beam steering setup for advanced research in a diffractometry using a laser beam and a sample, precise readings and controls of both end effectors and devices are of key importance. Due to the complexity of motion in 3-D, multi-axis systems can present many issues without careful design and considerations. Newport Hexapods provide innovative user-definable coordinate systems to answer this challenge, leading the way of user-friendly multi-axis positioning platforms available on the market. This tech note illustrates the three user-definable coordinate systems and helps with integration and configuration of the Hexapods in experimental setups or manufacturing process, thus to help maximize the benefits of using the line of Newport's Hexapod products.

To uniquely represent the position of a moving platform in three-dimensional space, one must specify its spatial location and angular orientation with three linear and three rotational coordinate values. The Newport HXP series of Hexapods uses a **Cartesian coordinate system** for translation and the **Bryant angles** for rotation, which are frequently used in robotics and aviation. (See Figure 1) A position (X Y Z U V W) represents a XYZ location of the center point of the platform in a 3-D space in right-handed Cartesian coordinate system as well as orientation in roll, pitch and yaw (U V W, Tait-Bryan angles definition).

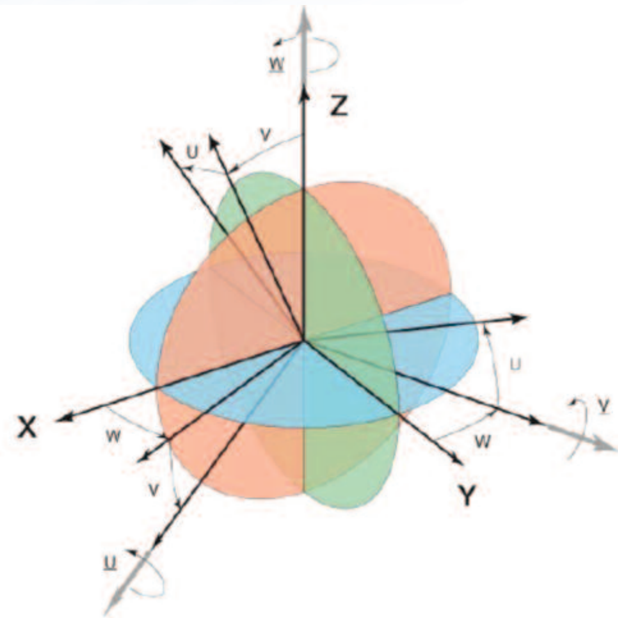


Figure 1: Setup Configuration for Optical Quality Testing with Gimbal

To understand how the position (X Y Z U V W) is reached in the Hexapod coordinate systems, consider a move defined by position (X Y Z U V W) starting from the position (0 0 0 0 0 0). The Tool coordinate system is set to the position (X Y Z) in the Work coordinate system. Then, it rotates about the z axis of the Tool coordinate system (W), rotates about the new y axis of the Tool coordinate system (V) and rotates about the new x axis of the Tool coordinate system (U). All rotations are made clockwise for positive rotations.

When positioning commands are given in Cartesian coordinates and Bryant angles, they are transformed by the Newport HXP controller to the specific positions and velocities for each of the six Hexapod actuators before execution. All individual positions for the six actuators are taken as a set to define a unique position (location and orientation) of the Hexapod in the coordinate system. The transformation of coordinate to the actuator lengths is fully transparent.

Understanding the Tool, Work and Base coordinate systems

How does the Hexapod uniquely determine the position (location and orientation in X Y Z U V W)? As we are familiar with scalar fields in mathematics, a point is a sufficient geometric element to specify spatial positions (X Y Z) in a 3-D space. However, this representation is insufficient to identify directions associated with angular positions (U V W). It is however

Motion in 3-D: Newport Hexapod Coordinate Systems

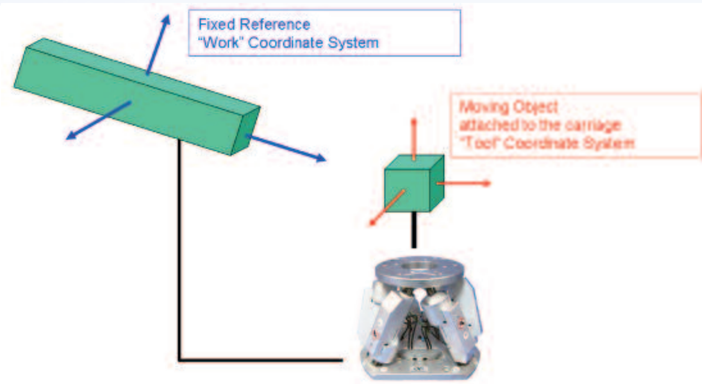


Figure 2: Illustration of Work and Tool Coordinate Systems

possible to use a coordinate set to uniquely describe the (X Y Z U V W) position of a platform in 3-D space. Consider a coordinate system with an origin (X=0, Y=0, Z=0) that corresponds to the center of the top surface of the Hexapod carriage and the Z-axis orthogonal to the carriage. This configuration is the default setting for the Tool Coordinate System, which is defined relative to the moving carriage of the Hexapod.

To read the position of a moving Hexapod carriage from the Tool Coordinate System, a fixed, second coordinate system is necessary as a reference. This reference coordinate system is called the Work Coordinate System. In essence, the position of the moving carriage of a hexapod is always understood as the position of the Tool coordinate system inside the Work coordinate system. (Figure 2) In the default configuration of the HXP, the Work coordinate system has the following configurations: 1) the X- and the Y-axis origins are centered on the base plate; 2) the height of the Z-axis origin is set to a pre-determined value (For the reference position (0 0 0 0 0 0), the upper surface of the top plate is close to mid travel for the HXP50 and the HXP1000, and it is close to the lower extreme position for the HXP100); 3) The XY plane of the coordinate system is parallel to the base plate; 4) The W-axis (Yaw orientation) matches the orientation defined in the Hexapod drawing. (The motor cables point in the positive X-axis direction of the World coordinate system.)

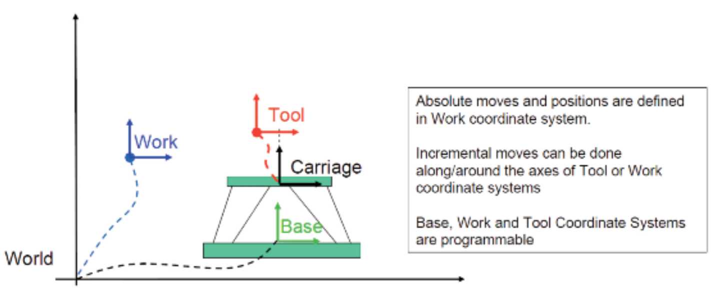


Figure 3: Illustration of Work, Tool and Base Coordinate Systems in relation to the Hexapod Carriage and World

The **World Coordinate System** is an absolute fixed reference to the outside world. It is defined such that, in the default configuration, the center of the world coordinate system is at the center of the lower surface of the Hexapod base plate, Z is orthogonal to the base plate, and X is in the direction of the motor cables.

While the Work and the Tool coordinate systems are essential for users to understand before using the Hexapod, the Base coordinate system and Carriage are important for understand the operating principles behind and behaviors of Hexapod motion (Figure 3). The Base coordinate system and Carriage can be considered as internal values for the Hexapod as they are linked to the physical positions of the joints, enabling Hexapod coordinate assignments according to the positions read from the integrated encoder in the Hexapod actuator legs. The Carriage, where the top of the struts is linked, is used as a reference to set the Tool coordinate system. The Base coordinate system, where the bottom of the struts is linked, is used to reference the Hexapod position in the World coordinate system. The Base coordinate system is always defined as (0 0 0 0 0 0) in the XY plane where all lower joints of the Hexapod struts are connected. In the default setting of the Base coordinate system, the center of the lower surface of the Hexapod base plate has the World coordinates X=0, Y=0, Z=0.

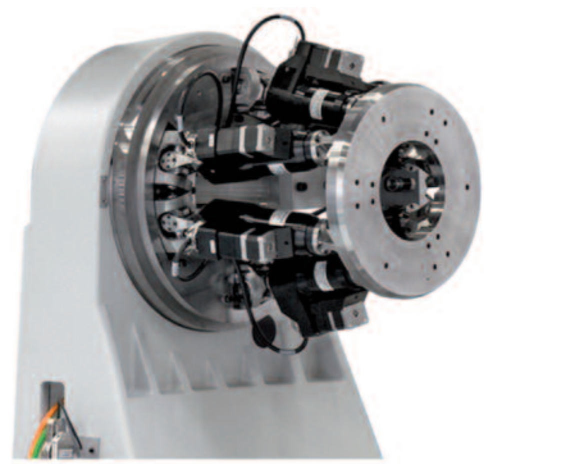


Figure 4: A Hexapod mounted with vertical base configuration on the RVU500 rotary stage

Motion in 3-D: Newport Hexapod Coordinate Systems

Why is the Base coordinate system defined relative to the World coordinate system, instead of the Work coordinate system? By referencing the World coordinate system, it is possible to take into account any change in the position of the Hexapod without affecting the motion commands of the Tool in the Work coordinate system. A good example is a Hexapod mounted on a moving platform at the center of a multi-axis goniometer in a diffractometry application. (Figure 4) When the Hexapod itself is rotated or moved to a different location after re-configuring the setup or after servicing, a simple relocation of the Hexapod Base coordinate systems allows using the same programmed motions from a prior configuration.

Hexapod Movements (Move Absolute and Move Incremental):

A classical motion control system uses two types of basic motion commands; absolute move and relative move. Similarly, the Hexapod uses three distinctive modes of operations that are 1) Absolute Move in Work 2) Incremental Move in Work and 3) Incremental Move in Tool. An incremental move in the Hexapod is distinguished from a relative move for other positioners because the series of incremental motions are not always cumulative. The moves follow the rotation principle in 3-D space. For example, starting from Hexapod positon (X1, Y1, Z1, U1, V1, W1) and then making an incremental move of (X2, Y2, Z2, U2, V2, W2) will not always bring Hexapod to the absolute position (X1+X2, Y1+Y2, Z1+Z2, U1+U2, V1+V2, W1+W2).

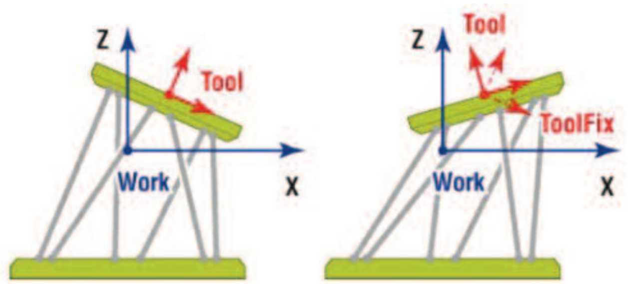


Figure 5: (Left) Hexapod at position (X 0 Z 0 V 0)
(Right) After HexapodMoveIncremental (HEXAPOD, Tool, 0, 0, 0, 0, V, 0)

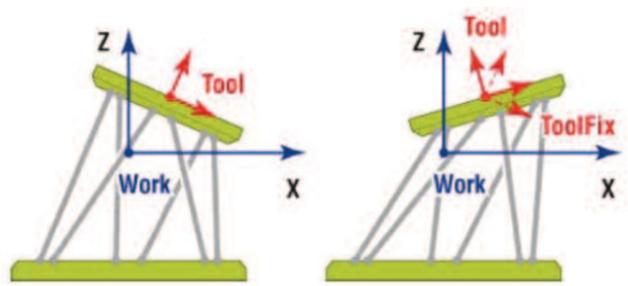


Figure 6: (Left) Hexapod at position (X Y Z U V W)
(Right) after HexapodMoveIncremental (HEXAPOD, Work, 0, 0, 0, 0, V, 0)

How is the 'Incremental Move in Tool' really different than the 'Incremental Move in Work'? An incremental move in the Tool coordinate system is made along the axes of the Tool coordinate system (moving with the carriage) and the center of rotation is at an interim origin of the Tool coordinate system. This means that, when the carriage moves in XYZ, the center of rotation in Tool also moves to the new center location of the carriage. On the other hand, an incremental move along the Work coordinate system uses the fixed Work coordinate system as a reference. Therefore, the center of rotation in Work does not change when the carriage moves in XYZ.

Figures 5 and 6 illustrate examples to show a clear difference between 'Incremental Move in Tool' and 'Incremental Move in Work'. For incremental rotations around the Tool coordinate (Figure 5), the lateral positions (X Y Z) of Tool in Work do not change. On the other hand, incremental rotations around the Work coordinate (Figure 6) change the XYZ position of the Hexapod, unless the Hexapod is at X = Y = Z = 0.

The incremental moves in the Hexapod enable easy, intuitive motions without complex mathematics or manual coordinate transformations by users. For instance, an incremental move in the Work coordinate system allows users to move and align a sample position to a laser beam or a tool. Once the move is completed, an incremental move in the Tool coordinate system allows bringing adjacent points of the sample into the laser beam or the tool.

Two programmable pivot points:

Newport Hexapods have two programmable pivot points, represented by the origin of the Work coordinate system and the origin of the Tool coordinate system. These pivot points can be located anywhere in space via the setup commands or the configuration file. This approach enables easy alignment relative to the external reference of lasers, shutter devices, camera or other types of sensors. The primary pivot point (Work) is ideal for the starting alignment of a sample to an incident laser beam (or a workpiece to a cutting tool). The second pivot point (Tool) allows positioning the sample along Tool

Motion in 3-D: Newport Hexapod Coordinate Systems

axes relative to the beam from the starting position, allowing the material processing on the surface of the sample, as an example. This two pivot concept also applies to the inspection, metrology or traditional machining processes.

Typical applications for the Hexapod include optical alignment and calibration, biomedical engineering and surgical robotics, satellite and telescope positioning, sensor metrology and calibration, and semiconductor test and metrology. For additional information, please visit the Newport HXP series Hexapod webpage or contact Newport sales and application engineers at tech@newport.com.

Figure 7: Photos of Newport HXP100, HXP1000 and HXP50 (from left to right)

Newport Experience | Solutions

Newport Corporation, Global Headquarters
1791 Deere Avenue, Irvine, CA 92606, USA
PHONE: 1-800-222-6440 1-949-863-3144 FAX: 1-949-253-1680 EMAIL: sales@newport.com
Complete listings for all global office locations are available online at www.newport.com/contact

www.newport.com

	PHONE	EMAIL		PHONE	EMAIL
Belgium	+32-(0)0800-11 257	belgium@newport.com	Irvine, CA, USA	+1-800-222-6440	sales@newport.com
China	+86-10-6267-0065	china@newport.com	Netherlands	+31-(0)30 6592111	netherlands@newport.com
France	+33-(0)1-60-91-68-68	france@newport.com	United Kingdom	+44-1235-432-710	uk@newport.com
Japan	+81-3-3794-5511	spectra-physics@splasers.co.jp	Germany / Austria / Switzerland	+49-(0)6151-708-0	germany@newport.com
Taiwan	+886 -(0)2-2508-4977	sales@newport.com.tw			

DS-101202